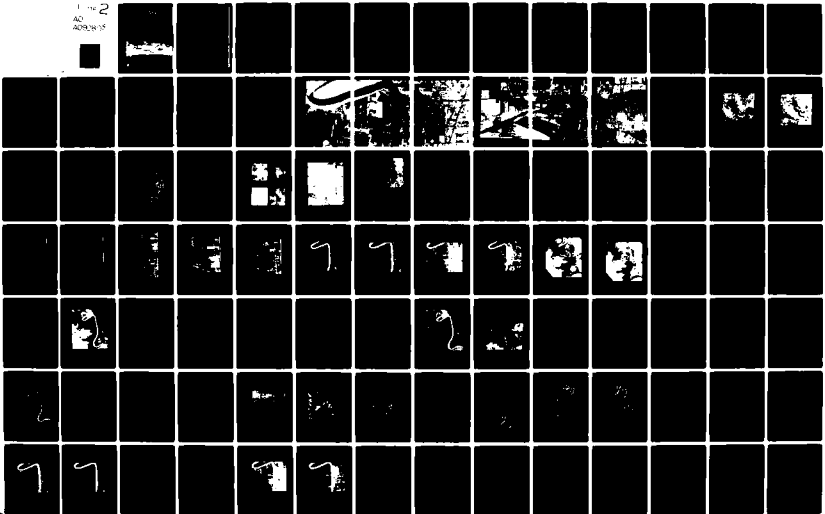
AD-A092 807 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 8/6
ACQUISITION OF TERRAIN INFORMATION USING LANDSAT MULTISPECTRAL --ETC(U)
SEP 80 M H SMITH, H STRUVE

UNCLASSIFIED WES-TR-M-77-2-3 NL

1 of 2
AD
A092807



AD A092807

LEVEL II

A045 87

(2)

TECHNICAL REPORT M-77-2

ACQUISITION OF TERRAIN INFORMATION USING LANDSAT MULTISPECTRAL DATA

Report 3

APPLICATION OF AN INTERACTIVE CLASSIFICATION PROCEDURE IN SOUTH LOUISIANA

by

Margaret H. Smith and Horton Struve

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

Rpt 1
A044 99

September 1980

Report 3 of a Series

Approved For Public Release; Distribution Unlimited

Prepared for Assistant Secretary of the Army (R&D)
Department of the Army
Washington, D. C. 20310

"Original contains color plates: All DTIC reproductions will be in black and white"

Under Project 4A161101A91D, Task 02, Work Unit 110-Q6
and Earth Resources Satellite Program, Work Unit 31584

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (9) Technical Report M-77-2	2. GOVT ACCESSION NO. AD-A093	3. RECIPIENT'S CATALOG NUMBER 807
4. TITLE (and Subtitle) ACQUISITION OF TERRAIN INFORMATION USING LANDSAT MULTISPECTRAL DATA. Report 3. APPLICATION OF AN INTERACTIVE CLASSIFICATION PROCEDURE IN SOUTH LOUISIANA.		5. TYPE OF REPORT & PERIOD COVERED Report 3 of a series
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Margaret H. Smith and Horton Struve		8. CONTRACT OR GRANT NUMBER(s) (17)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) Project 4A161101A91D, Task 02, Work Unit 110-Q6, and see 18 below
11. CONTROLLING OFFICE NAME AND ADDRESS Assistant Secretary of the Army (R&D) Department of the Army Washington, D. C. 20310 (12) 129		12. REPORT DATE (11) September 1980
		13. NUMBER OF PAGES 118
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (14) WES-TR-M-77-2-3		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Earth Resources Satellite Program, Project 0600, Task 31584, Work Unit 31584

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Data acquisition
Landsat (Satellite)
Multispectral data
Spectrum analysis
Terrain classification

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the application of an interactive Landsat classification procedure in South Louisiana. The procedure, discussed in Report 2 of this series, is an interim solution to the problem of mapping very large areas in terms of relatively crude categories in very short periods of time.

The area selected for study was Baton Rouge and vicinity. This area includes a portion of the Mississippi River, wooded areas, farm land, and various
(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

032100

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued).

categories of urban land use. The procedure successfully classified the water, woods, farm land, and industrialized urban categories, but failed to correctly classify residential urban areas due to the nonuniqueness of their spectral signatures.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

This report is the third of a series dealing with the manipulation and interpretation of Landsat digital data. The concepts and procedures reported herein were developed under the In-House Laboratory Independent Research Program, Project 4A161101A91D, Task 02, Work Unit 110-Q6, "Use of Automated Procedures for Change Detection and Land-Use Mapping from Satellite Data," and the Earth Resources Satellite Program, Work Unit 31584, "Programmed Identification and Mapping of Forest and Habitat Categories."

The first report (TR M-77-2, Report 1) of this series discussed image interpretation and the theories and procedures for handling reflectance geometry, terrain slope, atmospheric attenuation, and shadow effects. These extrinsic effects were analyzed and an analytic expression for their correction was presented. The second report (TR M-77-2, Report 2) discussed the development of a semiautomated procedure to classify Landsat radiance data in terms of preselected land-use categories or terrain types.

The work in this study was done during the period January 1977-September 1980 by personnel of the Environmental Simulation Branch (ESB) under the direct supervision of Mr. H. W. West, Project Manager, and Mr. J. K. Stoll, Chief, ESB. At the beginning of the study, the ESB was part of the Environmental Systems Division (ESD), Mobility and Environmental Systems Laboratory (MESL), U. S. Army Engineer Waterways Experiment Station (WES); the study was under the general supervision of Messrs. B. O. Benn, Chief, ESD, and W. G. Shockley, Chief, MESL. ESD later became part of the Environmental Laboratory (EL) of WES; the study and report were completed under the general supervision of Dr. John Harrison, Chief, EL.

Dr. H. Struve (ESB) developed the interactive classification procedure used in the study. The report was prepared in FY 80 by Ms. M. H. Smith (ESB) and Dr. Struve. Mr. A. N. Williamson, Computations and Analysis Group, Mobility Systems Division, Geotechnical Laboratory,

produced the graphics material of the Landsat digital data used in the preparation of this report.

COL John L. Cannon, CE, and COL Nelson P. Conover, CE, were Commanders and Directors of WES during the period of study and report preparation. Mr. F. R. Brown was Technical Director during this period.

CONTENTS

LIST OF FIGURES

LIST OF FIGURES

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. customary)	1.609344	kilometres

ACQUISITION OF TERRAIN INFORMATION USING LANDSAT MULTISPECTRAL DATA

APPLICATION OF AN INTERACTIVE CLASSIFICATION PROCEDURE IN SOUTH LOUISIANA

PART I: INTRODUCTION

Background

1. The capability of a Landsat satellite to view the earth's surface from a vantage point 900 to 950 km above the earth has revolutionized the concept of data collection for both military and Civil Works purposes. Not only does the "eye in the sky" see from this perspective, but it consistently follows its track, circling the earth with such precision that, at regular intervals, it views (in a continuum) approximately the same strip of the earth's surface. On board the satellites of the Landsat Observation System, multispectral scanners (MSS) and return beam vidicon cameras (RBV) continually sample the spectral reflectances from the earth's surface and record them on magnetic tape for analysis and image production. These tapes also contain ephemeris data and other information about the environment at the time of collection that permit reasonable assessment of the quality of the data from the earth's surface. Thus, the Landsat System puts a mass of current, reliable data, collected by consistent procedures, in the hands of geographers, strategists, economists, and researchers for use in their search for expanded knowledge of the surface of the earth, both in our nation and around the world.

2. On the domestic scene, in addition to the obvious applications of Landsat data analysis for defense strategy, analyses of the data hold promise for monitoring the use of the nation's waterways and coastal regions, monitoring waste disposal, assessing flood damage, locating urban sprawl and industrial development, and monitoring change in land use.

3. Potential worldwide military applications are for military

support information and for building data banks to be used in future research or in times of emergency. Nonmilitary needs that could be served by Landsat data analyses are in the area of protection of water resources and monitoring the changes made by the exploitation of other natural resources. The emerging third world nations struggling to become responsible and self-sufficient could be served by knowledge of their nations' land, its use, and changes brought about by various land-management methods.

4. Landsat data have been available only a very short time, the first satellite being launched in July 1972. There are now three satellites, the second, Landsat 2, launched in January 1975, and the third, Landsat 3, launched in early 1978. The first two sampled reflectance values from the earth's surface by six sets of four sensors each in the spectral range of 0.5 through 1.1 μm. The third satellite carries, in addition to these four sensor sets, a fifth sensor in two of the six sets that operates in the thermal infrared region from 10.4 to 12.6 μm. This sensor, operating in the fifth spectral reflectance band, will result in one-third the resolution of the other four spectral bands. Computer compatible tapes (CCT's) obtained from Landsat 3 will not carry information from the new band five until the data have been thoroughly evaluated. Early indications suggest possible distortion of data beyond recovery, preventing the availability of these kinds of data until the launching of another satellite. Additional information on the operation and products of satellites in the Landsat Observation System is available in published reports.*

5. Many investigators, private as well as government agencies, have been occupied with the analysis of Landsat data. Among the government agencies, the U. S. Army Engineer Waterways Experiment Station (WES)

---

* National Aeronautics and Space Administration. 1976. "Landsat Data Users Handbook," Document No. 76SD4258, Goddard Space Flight Center, Greenbelt, Md.

Jaffe, L. 1975. "Inputs Requested from Earth Resources Remote Sensing Data Users Regarding Landsat-C Mission Requirements and Data Needs," Attachments A-E, National Aeronautics and Space Administration, AN-OA-76-B, Goddard Space Flight Center, Greenbelt, Md.

has taken keen interest in the potential of Landsat data to identify water bodies, land use, and wetlands; and to detect the transport and deposition of suspended material in streams and rivers, the illegal use of marginal river and coastal boundaries, and the changes in land use caused by man and by natural phenomena. In these endeavors, the analysis of Landsat data indicates its potential for monitoring land use and its changes. However, the analysis procedures are still in an almost embryonic state. The information resides in the analogs, and the digital transforms are stored on CCT's for users to interpret in their investigative studies. While much has been accomplished by National Aeronautics and Space Administration (NASA) researchers in their transfer of data to the CCT's, interpretation remains for the accomplishment of the user. The first two reports* in the "Acquisition of Terrain Information Using Landsat Multispectral Data" series describe a procedure for transforming and interpreting Landsat data.

6. The first report (TR M-77-2, Report 1) discussed image interpretation and the theories and procedures for handling reflectance geometry, terrain slope, and atmospheric and shadow effects. These extrinsic effects were analyzed and a consolidation equation for their correction was presented. The equation can be used to compute terrain radiance as a function of wavelength as measured by the Landsat Sensor System in watts per square centimetre per micrometre ($Wcm^{-2}\mu m^{-1}$). Plates 1-4, taken from Struve, Grabau, and West (1977a), show a generalized diagram of procedural steps to interpret a Landsat image and explain the detailed steps in atmospheric, slope, and shadow correction procedures.

7. The second report (TR M-77-1, Report 2) discussed the

---

* Struve, H., Grabau, W. E., and West, H. W. 1977a. "Aquisition of Terrain Information Using Landsat Multispectral Data; Correction of Landsat Spectral Data for Extrinsic Effects," Technical Report M-77-2, Report 1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Struve, H., Grabau, W. E., and West, H. W. 1977b. "Aquisition of Terrain Information Using Landsat Multispectral Data; An Interactive Procedure for Classifying Terrain Types by Spectral Characteristics," Technical Report M-77-2, Report 2, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

development of a semiautomated procedure to classify Landsat radiance data in terms of preselected land-use categories or terrain types. The procedure can be applied directly to the primary data on the CCT's, assuming that the relations among the primary data are the same as those among processed data; i.e., classification results would not be improved if applied to processed or corrected data instead of primary data. Actual data from the Mississippi River floodplain north of Vicksburg (Satartia site) were used in the development process. The interactive procedure described in Struve, Grabau, and West (1977b)* was very successful in the classification of water and forest pixels in the data from the demonstration site. Computer programs developed in this procedure can be used easily by engineers or trained technicians in an interactive fashion to classify water and forest from Landsat data, provided some preselected guidance is available. Plates 5 and 6, taken from Report 2, describe the procedural steps for a generalized guided classification of Landsat data and detailed steps in a procedure for the selection of classification criteria.

Objective and Scope

8. The overall objective of the study series is to develop and demonstrate automated procedures for obtaining land-use classifications from Landsat data that are acceptable for use by the Corps Divisions and Districts in detecting land-use change and producing land-use maps. The specific objective of this study was to demonstrate the application of the guided classification procedure (in locations other than the Satartia site) to identify water, forested, and nonforested land use; to explore the possibility of extending the procedure to include urban and open space classes; and to investigate an unguided classification procedure.

Approach

9. Landsat data from two flights over Baton Rouge, La., and

* Ibid.

vicinity were studied: an older flight in October 1972 (tapes on hand at WES) and a more recent flight in February 1977 (tapes ordered from the Earth Resources Observation System (EROS) Data Center*). February 1972 aerial photography was used with the October 1972 overflight, and February 1974 aerial photography was obtained for the February 1977 overflight. At the time of the study, 1974 photography was the latest available. The procedural steps outlined in Plates 5 and 6 were followed to identify water, forest, and other (nonforest, nonwoods) land use in the Baton Rouge vicinity. Automated procedures were developed to translate the data from satellite magnetic tape to a standard WES format for interpretation, to extract data for specific geographical locations, and to sort data into unique signatures and count their occurrence. Procedures to rectify Landsat data to aerial photography and an automated procedure to rectify Landsat data to Universal Transverse Mercator (UTM) coordinates were demonstrated. Both guided and unguided procedures were used to classify the Landsat data. A comparison of the land-use classes defined by the Landsat procedures and aerial photography interpretation was made for water, forest (or woods), urban, and open space (e.g., fields). Also, the land use interpreted from 1977 Landsat data was compared with 1972 Landsat data.

---

* U. S. Department of the Interior, Geological Survey, EROS Data Center, Sioux Falls, S. Dak.

PART II: DESCRIPTION OF THE STUDY

Study Sites

Baton Rouge and vicinity

10. Baton Rouge, La., and vicinity (Figure 1) was selected for study for the following reasons.

- a. It contains large areas of the land-use classes of interest in this study.
- b. It contains distinctive landmarks such as highway intersections, water bodies, and airport runways for use as reference points.
- c. There are several Landsat cloud-free scenes containing the region.
- d. Two universities and numerous State and Federal government offices are available for information.
- e. It is less than 150 miles* from WES.

11. The primary reason for selection was the presence of large areas of water, forested (or wooded), urban, and open areas (Figure 2). The Mississippi River occupies the center of the region, top to bottom, with several lakes and a portion of the Intracoastal Waterway included. Baton Rouge is on the east side of the river and contains a variety of land uses found typically in urban areas. There are oil refineries and other industrial areas, business sections, new and old residential areas, college campuses, and parks. On the west side of the river is an isolated oil refinery and a smaller urban area (Port Allen) consisting almost entirely of residences. A large wooded area surrounds the Intracoastal Waterway in the southwest portion of the region. The remainder of the region west of the river is open space covered by long, narrow sugarcane fields, scattered aggregates of dwellings, crossroad stores, and a small oil field or two.

---

* A table of factors for converting U. S. customary units of measurements to metric (SI) units is presented on page 6.

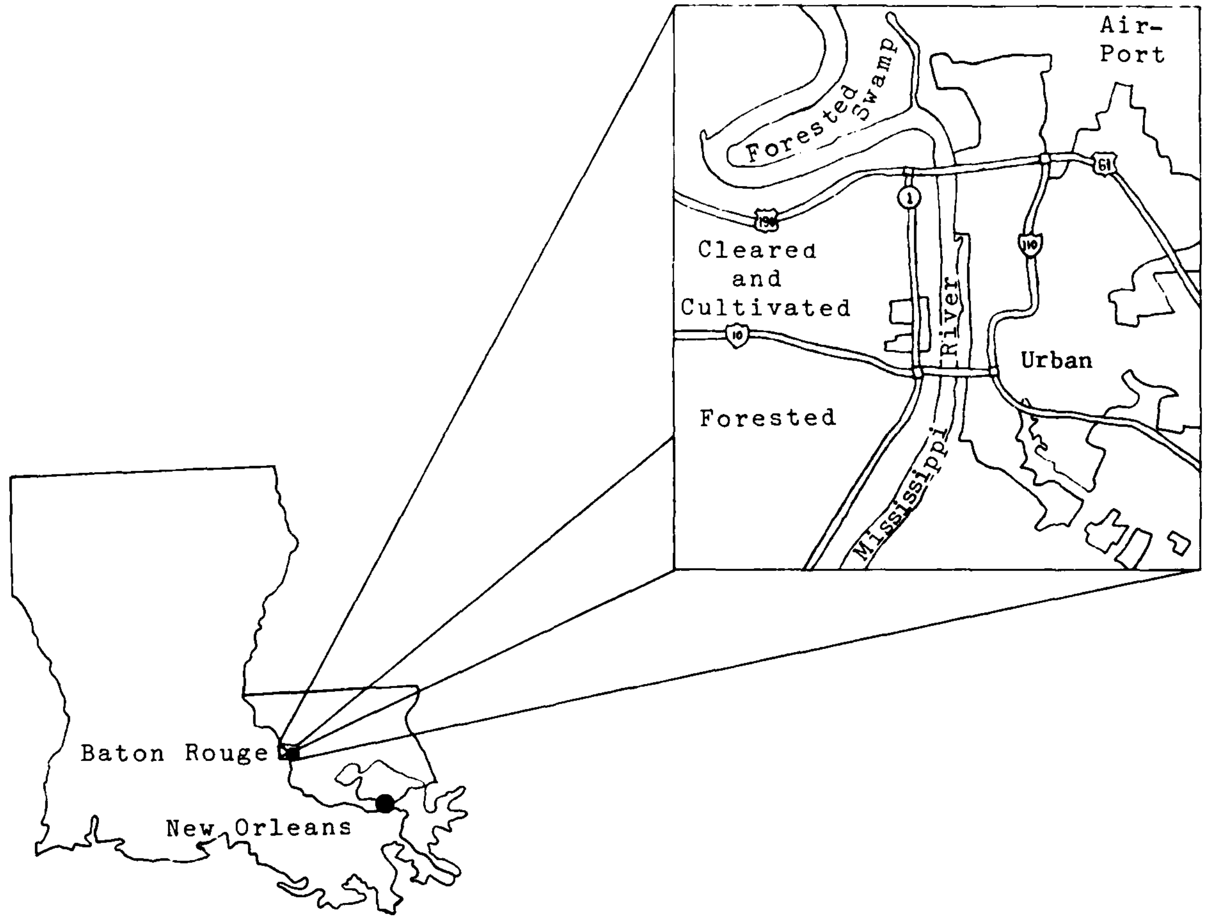
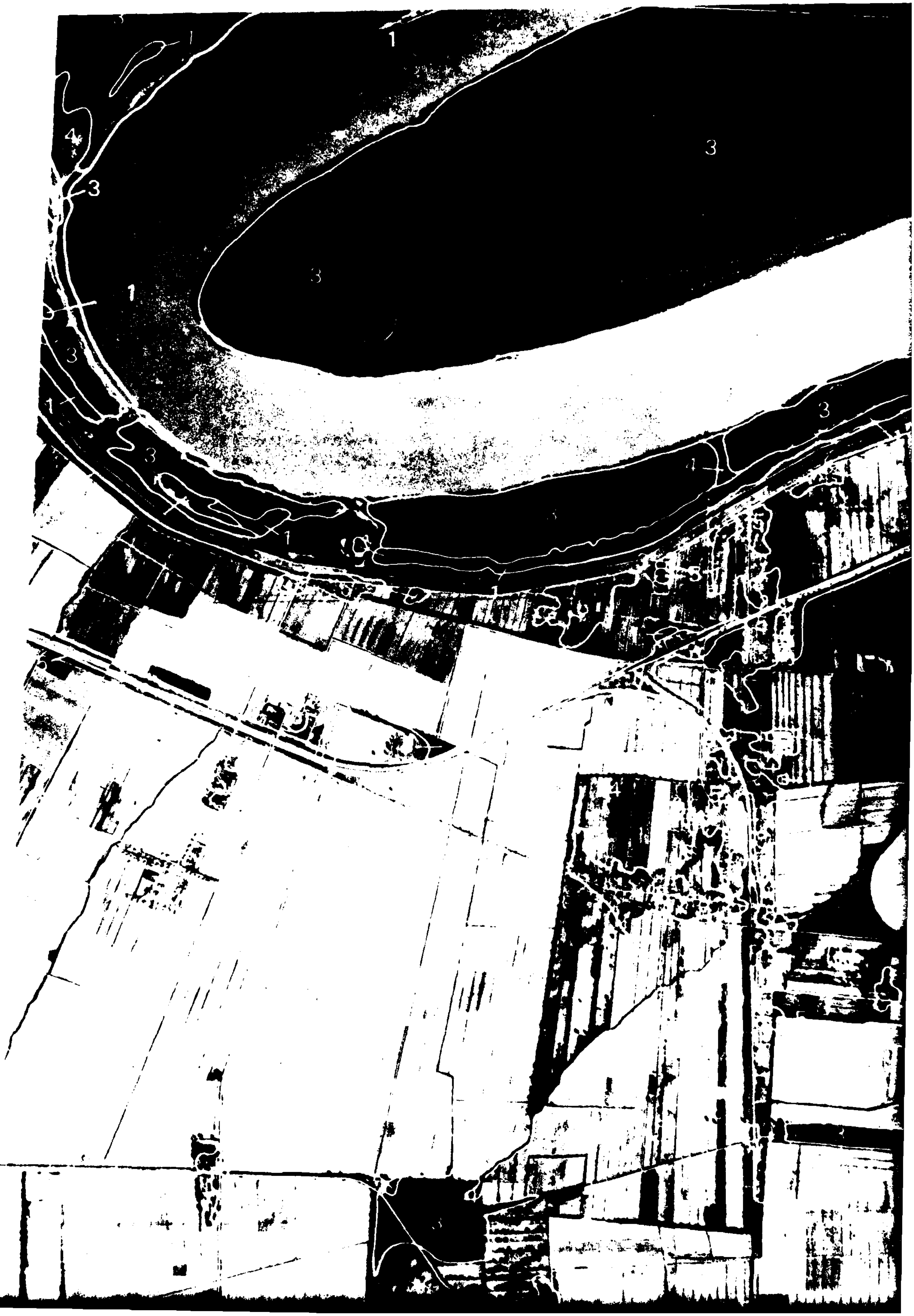
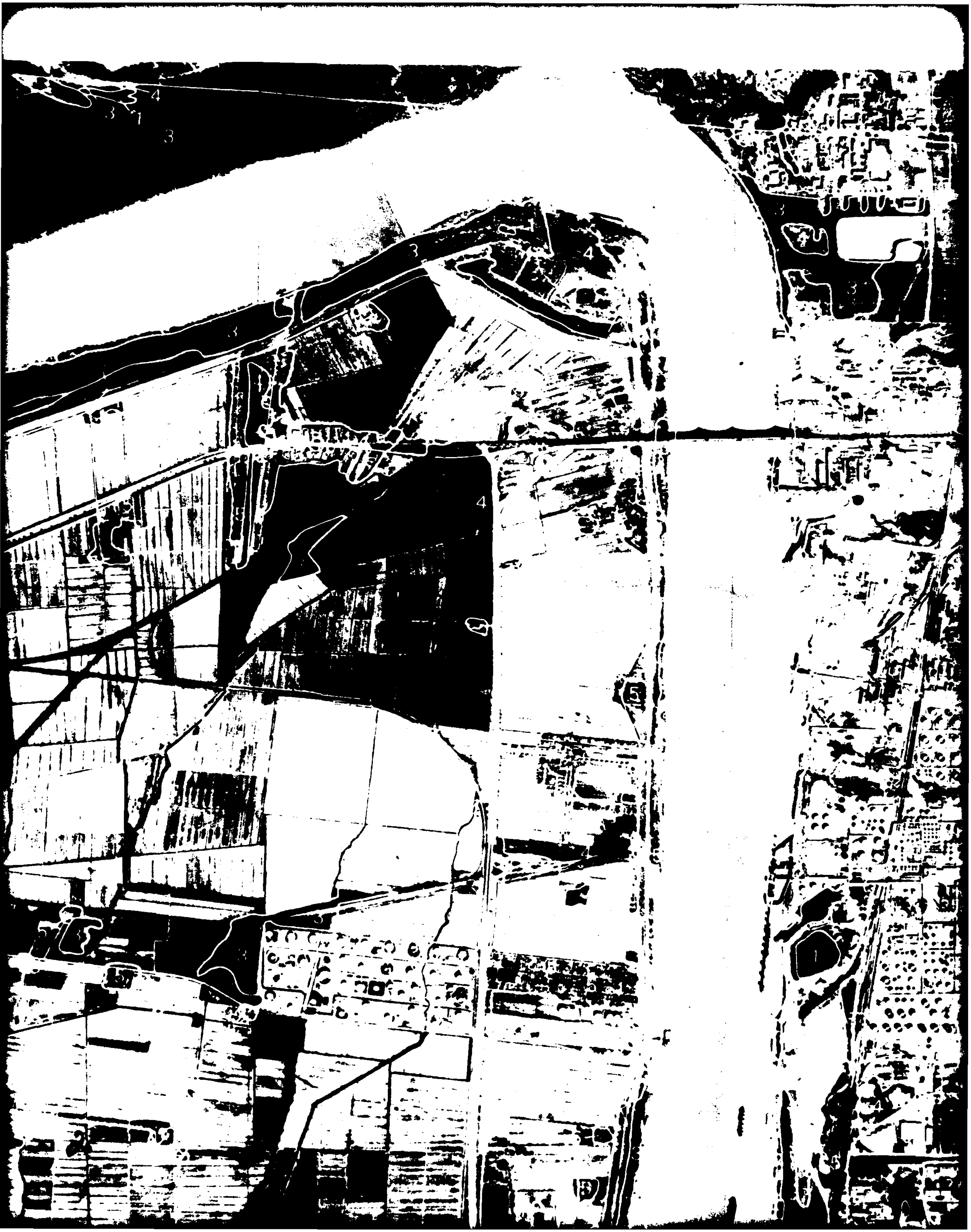


Figure 1. Location of study site



1.



1.

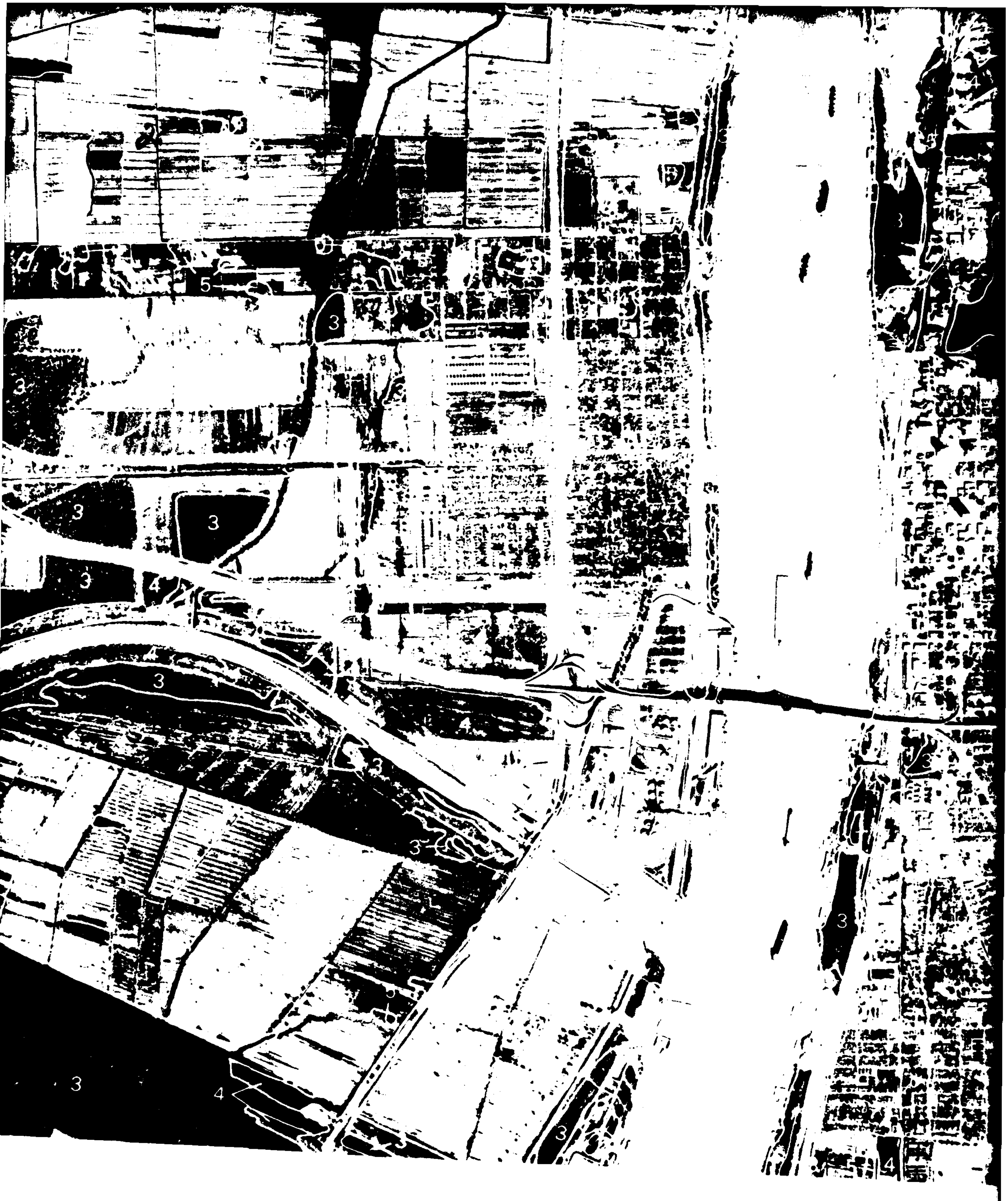


Figure 2. Baton Rouge and vicinity, February 1972 aerial photography

y

6

Port Allen

12. Port Allen, a subset of the Baton Rouge site including an oil refinery, woods, and fields, was chosen first for study because of the variety of land uses in a smaller area and because the concentration of houses in Port Allen offered an opportunity for better understanding of reflectance from residential areas. February 1972 aerial photography was used for land-use sample locations in interpretation of October 1972 Landsat data.

13. The classification for the Port Allen area was used in expanding the study area to the Baton Rouge site. The larger site was also classified using 1977 Landsat data with land-use interpretation from 1974 aerial photography.

Atchafalaya Basin

14. A site in the Atchafalaya Basin was used as a demonstration of the automated procedure to rectify Landsat data to UTM coordinates and to compare the success of the classification procedure to a previous manual land-use classification by interpretation of aerial photography.

Data and Equipment

15. Landsat data from two overpasses were used in this study, one on 1 October 1972 and one on 28 February 1977. Information about each overpass is included in Table 1. The images produced from data in band 5 of each overpass are shown in Figures 3 and 4. The 1972 data were collected by Satellite 1 and the 1977 data by Satellite 2. The CCT's were obtained from the EROS Data Center. The CCT's and their formats were discussed in Report 1 of this study series.* For details of Landsat data records, see the users handbook.**

16. The 1972 aerial photography was black and white photography acquired from the U. S. Department of Agriculture flown at 20,000 ft with a 6-in. focal length camera. An enlargement, 1:12,000, was used for land-use interpretation. The 1974 aerial photography was color infrared photography acquired from EROS Data Center flown by NASA aircraft

---

* Struve, Grabau, and West (1977a), op. cit.
** NASA, op. cit.

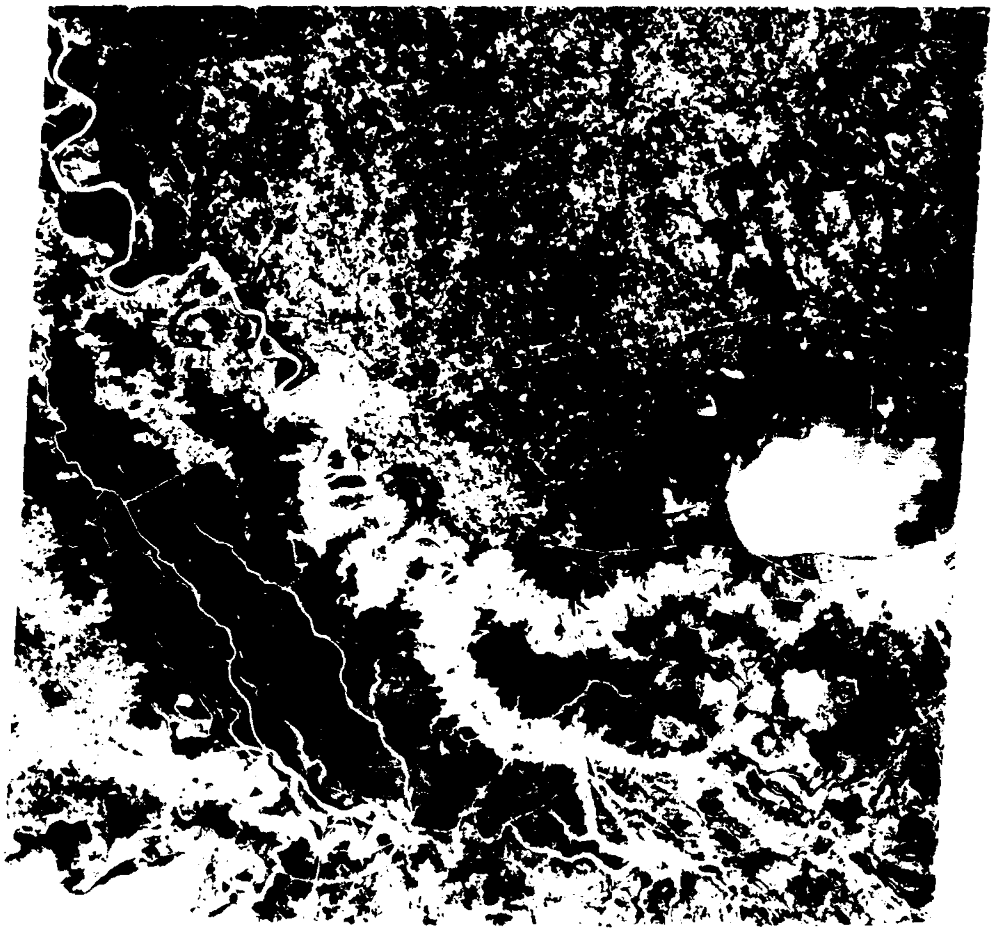


Figure 3. Band 5 image from Landsat overpass on 1 October 1972

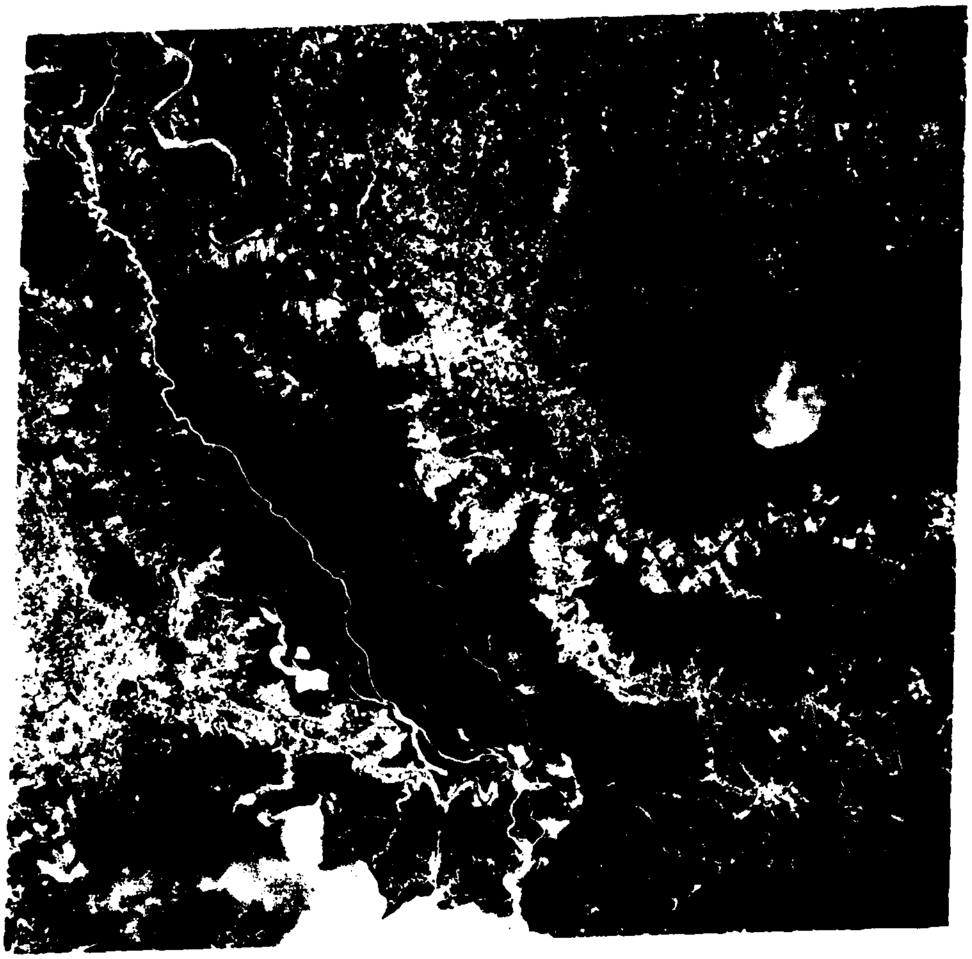


Figure 4. Band 5 image from Landsat overpass on 28 February 1977

at 131,500 ft. An enlargement, 1:65,500, was used in land-use interpretation.

17. A Honeywell G-635 computer was used to process the data. The computer consists of a 256 K word core memory, disc and magnetic tape storage subsystems, two line printers, and three Data Net 30 processors. The normal processing of Landsat data is similar to other array processing techniques by sequential procedures. One or more records (scan lines of data) are read sequentially into a buffer from a data tape. Sequential processing of each element in the record takes place with the resulting elements placed in an output buffer. When the buffer is filled, the data are written sequentially to an output tape or to a printer for hard-copy records. The input buffer is refilled and the process continues until all data are processed.

18. A line printer is used to print digital values extracted from the Landsat CCT. A program has been developed to print the extracted data in swaths that, when joined, present a digital picture of the desired portions of the Landsat scene.

19. A film reader/writer (described in Appendix A of Struve, Grabau, and West (1977b)*) is used to present a picture in shades of gray to represent the data. A light beam, with intensity varying as the input data values vary, moves across a piece of film mounted on a rotating drum. The light exposes a minute square of film producing a shade of gray determined by light intensity. Every data value is represented by a small gray square. When the squares are all produced, a "picture" of the data can be seen in shades of gray.

20. Since the film writer is restricted to the use of square elements in the picture, a procedure was developed to stretch the picture along the flight line of the satellite to more nearly represent the actual earth surface viewed by the sensor. This was accomplished for the site in this study by repeating every third and twentieth scan line of data. Sites in latitudes significantly different would require a different stretch or some geometric pixel size normalization procedure.

---

* Struve, Grabau, and West (1977b), op. cit.

21. The film writer is used to produce pictures of the land-use classes as interpreted from the Landsat data. The input to the film writer is a magnetic tape produced from the Landsat data array with class codes replacing the digital reflectance values of each pixel. This tape is read into the film writer, which produces a unique shade of gray for each land-use class resulting in a map of land use. The film writer products are black and white pictures for study, halftones for report or display products, or color masks for color prints.

Classification Procedures of the Subsite with 1972 Data

Landsat data

22. The procedures outlined in Plates 5 and 6 were followed to interpret and classify the Landsat data. Steps 1 and 2 were reversed in order to check the coverage and quality of the data before incurring the expense of acquiring CCT's (normally $200 for a scene). The images of the two Landsat overpasses were obtained. The location and quality were verified (Table 1), and the CCT's were ordered from EROS Data Center. The area of interest was located on the Landsat image, and, with the use of a Gerber variable scale, the corners were identified in terms of pixels and scan lines. Figure 5 shows the orientation of the Landsat data for the site on a topographic map, scale 1:250,000. Since the satellite travels at an angle of 9 to 11 deg from north in the latitude of Baton Rouge, the Landsat data including the area of interest are tilted at the Landsat orbit angle with the scan lines perpendicular to the line of flight.

23. The CCT's were read and unpacked from the Landsat format into a more convenient format for use on the 36 bit word Honeywell G-635 computer. This format, called WES format, places certain header information on the file and places data from one pixel into one computer word. A pixel is understood to be the spot of earth (approximately 57 by 79 m) viewed by a Landsat sensor at exposure time or the numerical value representing the reflectance from that earth spot. All the data from the west half of a scene reside on one WES-formatted tape, that from the east half

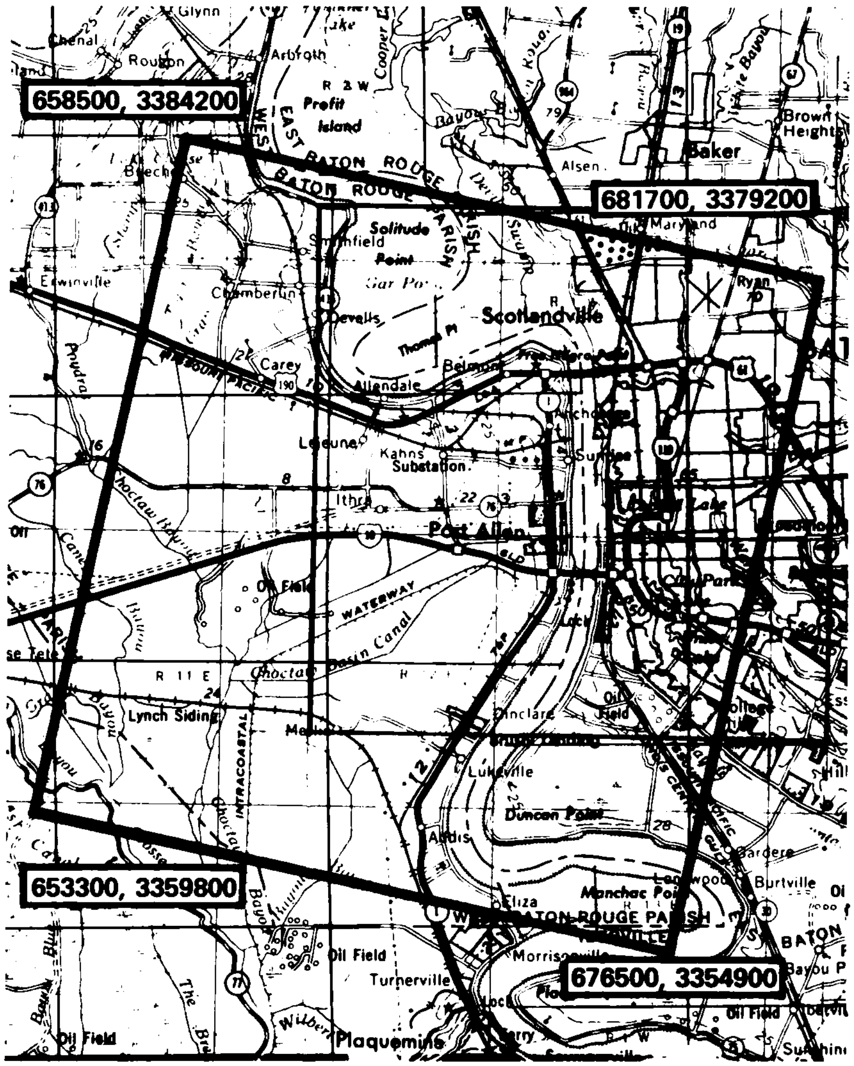


Figure 5. Topographic map showing UTM coordinates and orientation of extracted 1 October 1972 Landsat data containing area of interest

on another. The data from the area of interest were extracted from the WES-formatted tapes and were written on a new tape in the same format.

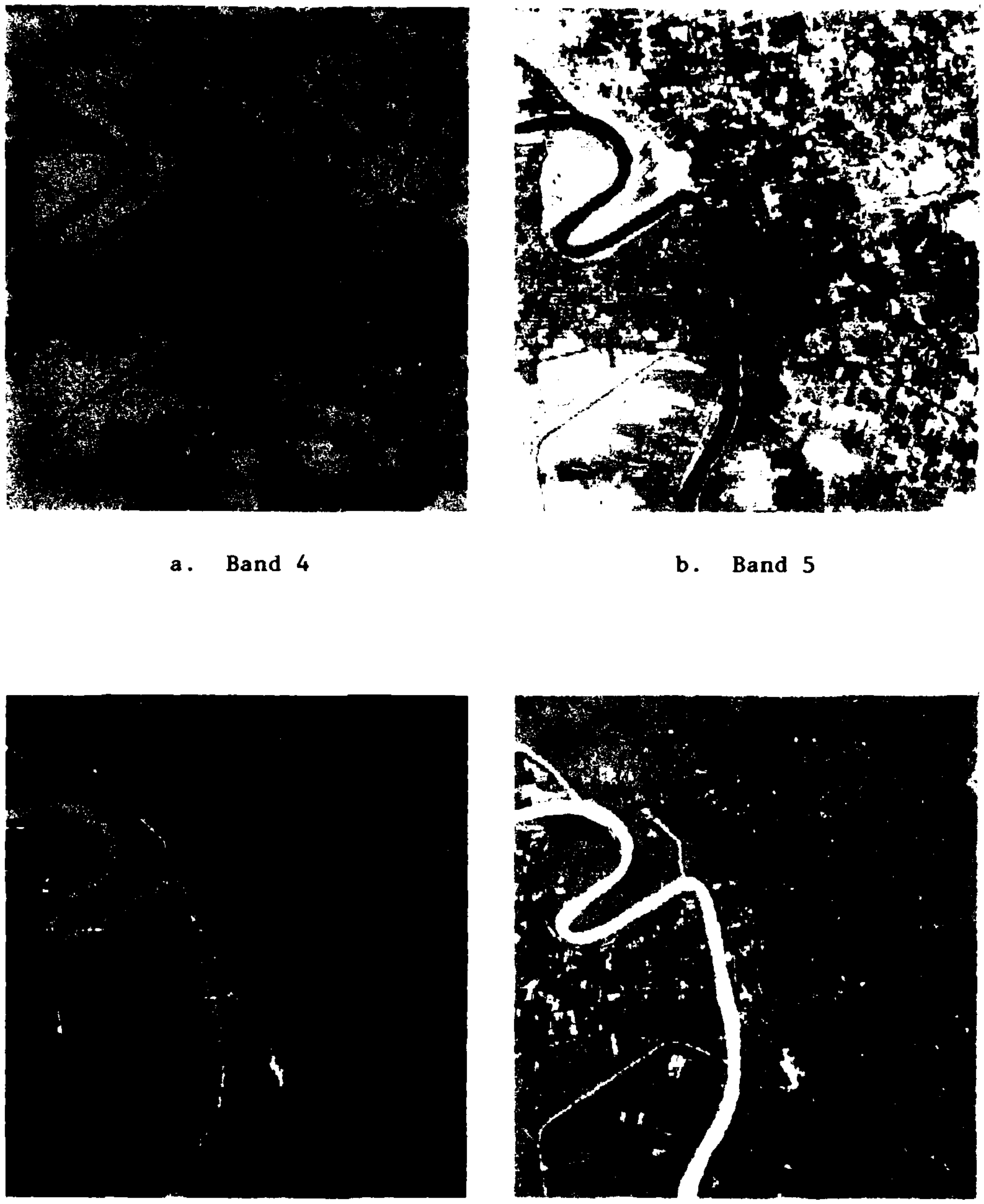
24. For a visual concept of the data, pictures of the site as sensed by each band were produced with the film writer by grouping the reflectance values into nine groups (Figure 6). Each group was then assigned a distinct shade of gray. Low reflectance values were assigned light shades and high values were assigned dark shades. The Mississippi River and lakes appear very light in band 7 compared to other surfaces due to their absorption of spectral wavelengths 0.8 to 1.1 μm. Bands 4 and 5 show greater contrasts of nonwater surfaces than bands 6 and 7, which should make them more useful for classifying forest and other nonwater surfaces. The lightest areas in bands 4 and 5 are forested areas. The flat-appearing area (next lightest) in band 4 to the west of the river in the center portion of the scene is occupied mostly with sugarcane fields and other open space. This area in the other bands appears to contain a wider range of values, which would increase the difficulty of separating open spaces and urban areas. There also appears to be a change in ratio of one land-use class to another from band to band; e.g. the ratio of forest to water appears to be quite different in band 4 from that in band 7.

Geometric accordance of Landsat data with aerial photography

25. The guided classification procedure requires some knowledge of the land-use classes as close to the time of the satellite overpass as possible. Samples are located on the available aerial photography and reflectance values from each band are extracted from the corresponding locations in the Landsat data. To locate the correct sample, the Landsat data must be brought into geometric accordance with the aerial photography. This was done by locating three points that were easily identified in both data sets to be used as transfer points.* For the Port Allen site (Figure 7), the three points A, B, and C were easily identified in the band 5 Landsat data (Figure 8). Points A and B are intersections of clearly defined highways, and point C is identified by the high

---

* Ibid.



a. Band 4

b. Band 5

c. Band 6

d. Band 7

Figure 6. Gray-scale pictures from Landsat scene, 28 February 1977, using Landsat reflectance values separated by bands

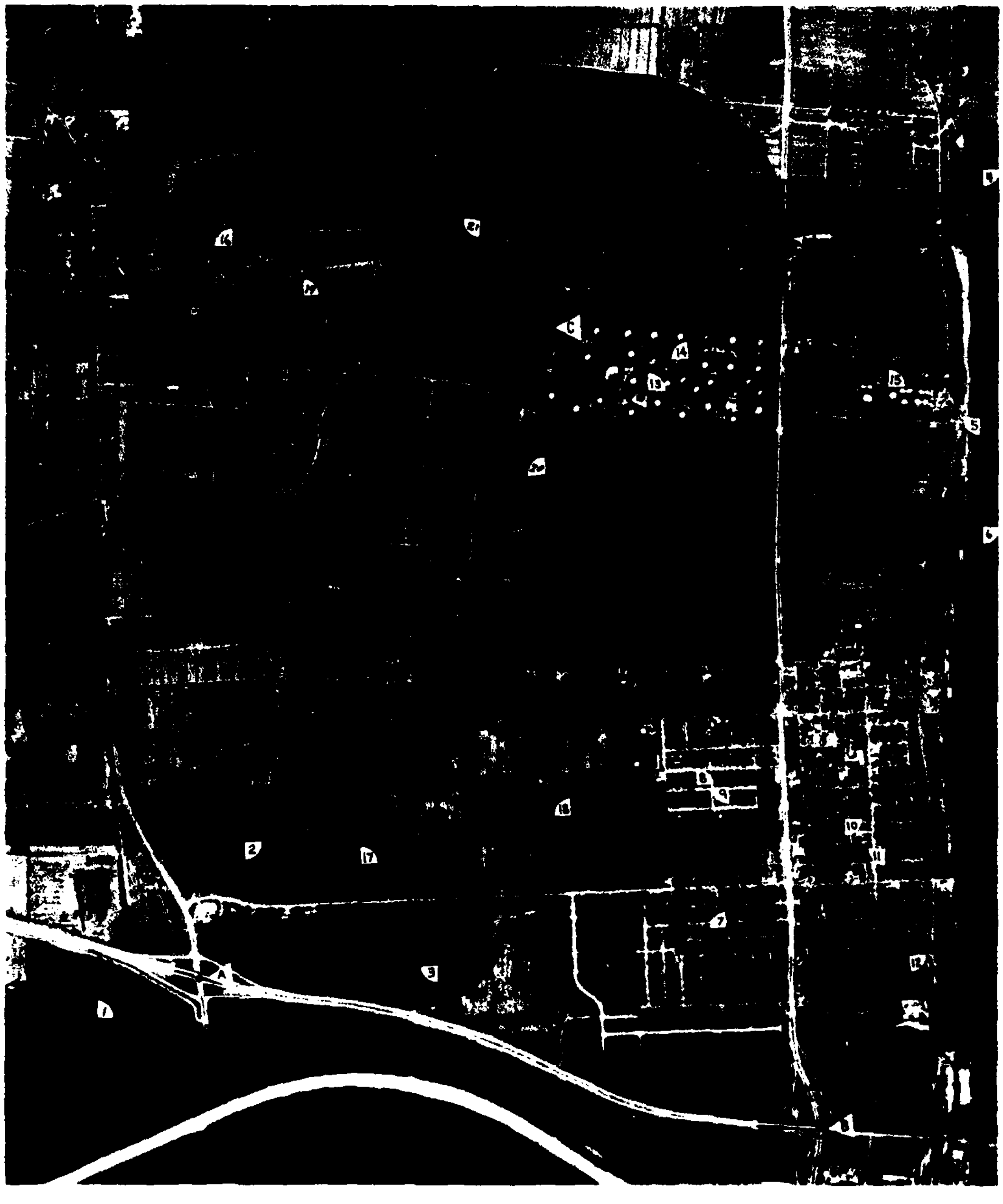


Figure 7. Location of sample sites (1-21) and transfer points (A-C) at the Port Allen site on February 1972 aerial photography

Figure 8. Transfer point locations for geometric accordance of 1972 Landsat with 1972 aerial photography data

reflectance from the northwest corner tank in rows of large oil storage tanks. The origin was assumed at A, and the distances of B and C from A with the pixel and scan numbers of the corresponding points in the Landsat data supplied the necessary information for the solution of the following equations:

$$"X_i \cos \theta_f - Y_i \sin \theta_f = N_{Xi} D_{Xi} \quad (1)$$

$$X_i \sin \theta_f + Y_i \cos \theta_f = N_{Yi} D_{Yi} \quad (2)$$

where

X_i and Y_i = X and Y air-photo coordinates of each respective transfer point

θ_f = Landsat flight-path angle with respect to true north

N_{Xi} = number of X-coordinate pixels of the transfer point within the Landsat data set

D_{Xi} = width of the Landsat pixel

N_{Yi} = number of Y-coordinate pixels of the transfer point within the Landsat data set

D_{Yi} = length of the Landsat pixel

Equations 1 and 2, representing each respective transfer point, were written with the appropriate substitutions and then simultaneously solved for the flight path angle θ and the size (D_X and D_Y) of the pixel within each Landsat data set. The average values for θ_f , D_X , and D_Y were then computed and used in the equations above to bring the terrain reference samples and CCT value data into geometric accordance."*

26. These transfer constants were then used to transfer the location of land-use samples to the Landsat pixels representing the spectral value of those samples. A listing of the digital Landsat band 5 data from the site area was obtained. For ease of selection, the Landsat data had been stretched (repeating third and twentieth scan lines) to present the data in a more easily recognized relationship to the photography. This stretching by inserting pixels over the same distance shortens the pixel length producing square pixels, $D_X = D_Y$. Table 2 lists the accordance data for 1 October 1972 Landsat data to February 1972 aerial photography and 28 February 1977 Landsat data to February 1974 aerial photography for Baton Rouge and vicinity. A computer program to determine these constants using unstretched data was developed and later inserted into the procedure. The program requires at least five transfer points over an area including the study area. This automated program was later used for rectifying classified portions of the Landsat scene to UTM coordinates on topographic maps. Table 3 lists the data for rectifying sites to UTM coordinates on a 1:250,000 topographic map.

---

* Ibid., pp 53-54.

Land-use sample
locations and data

27. Twenty-one land-use samples were selected from the February 1972 aerial photograph (Figure 7). Three samples (1-3) were selected from wooded areas; three were in water (4-6); six were in the urban residential area, Port Allen (7-12); three were in an urban industrial area (13-15); and six (16-21) were in open space. Equations 1 and 2 were used with the appropriate rectification constants and distances of the sample locations from transfer point A to determine the corresponding location (pixel and scan) in the Landsat data.

28. Reflectance values of each terrain sample and their eight surrounding terrain pixels were located in a digital listing of the Landsat data array. An example of the 3 by 3 arrays of data, Sample 1 (woods), is listed below.

Band 4	Band 5	Band 6	Band 7
22 22 22	13 13 12	34 32 32	21 21 21
20 21 24	13 11 13	33 33 35	22 22 21
20 22 22	12 12 12	34 34 34	22 20 22

Spectral data analysis
of Landsat 1972 data

29. The mean and standard deviation were computed for each 3 by 3 data array to determine if the samples were representative of the terrain type from which they were selected on the aerial photo. The three samples from woods (samples 1-3 in Table 4) had standard deviations less than 1.5. Struve, Grabau, and West (1977b)* established a standard deviation of 1.5 or less as a fair criterion for homogeneity of a sample; therefore, these samples were retained in the classification procedure. The water samples, samples 4-6 (Table 4), also contained none with deviations higher than 1.5. Most of the other 3 by 3 arrays have standard deviations much higher than the homogeneity criterion. This was to be expected from the nature of these kinds of land use. The mixtures of

---

* Struve, Grabau, and West (1977b), op. cit.

structures, trees, and open spaces in urban areas and the variety of planted fields, open pastures, wet areas, and plowed fields in open spaces present a "checkerboard" of high- and low-valued pixels in both urban areas and in open spaces. With the exception of the older residential areas, the band 4 reflectance from urban areas is generally higher than that from open space (Figures 2 and 6). For this reason, it was believed that urban could be separated from open space using band 4, and the samples were kept in the analysis even though they did not meet the homogeneity criterion.

30. Using the means of the four bands as representative signatures of the sample types, a similarity analysis was made with the clustering technique used by Struve, Grabau, and West (1977b).* The signatures with an allowable deviation were entered into the computer program. Signatures were then grouped by those falling within the allowable range of each band. The range of allowable deviation was increased until unique clusters were formed, i.e., samples did not overlap clusters. The results of this interactive cluster technique for Port Allen Landsat 1972 data are shown in Figure 9. A black dot indicates similarity of the two samples; e.g., sample 1 is similar to samples 2 and 3. Samples 20 and 21 were found to be more similar to urban (new residential) than to open space, so they were eliminated from the classification procedure. Because it did not encroach upon another class, sample 12 was kept with the urban (residential) samples even though it was not similar. The higher industrial urban reflectance samples clustered separately from the residential urban samples. Their range is shown as a double bar on the bar plots of terrain classes in Figure 10. In Figure 10, plots a-d are plots of the reflectance ranges of the clusters in Figure 9 by bands 4-7. These cluster ranges were derived from the cluster analysis with a deviation of 1.75 and are listed in Table 5. The range (mean ± 1.75) is listed for each band of each sample in the cluster. The cluster range was then determined as the range from lowest to highest reflectance in the cluster. From the bar plots of these ranges

---

* Ibid.

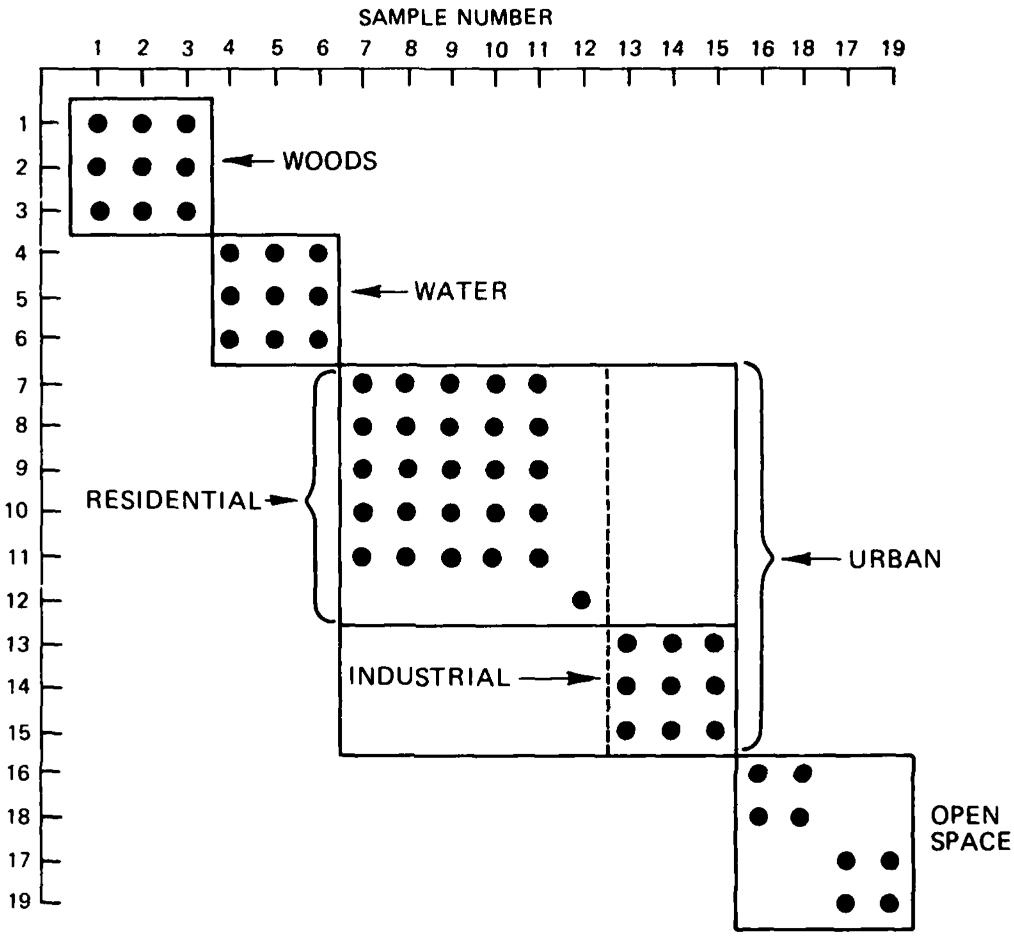


Figure 9. Cluster analysis of 1 October 1972 Landsat data from Port Allen, 1.75 variance

Figure 10), it can be seen that water is separated completely from other clusters in band 7; woods are separated in bands 4 and 5. There is no clear separation of urban clusters from open space anywhere except for those clusters with high reflectance in bands 4 and 5. Since a greater proportion is separated in band 4, it was used to establish the urban class limits. There is no chance, with this procedure, to separate lower reflectance in urban areas from reflectance in open space.

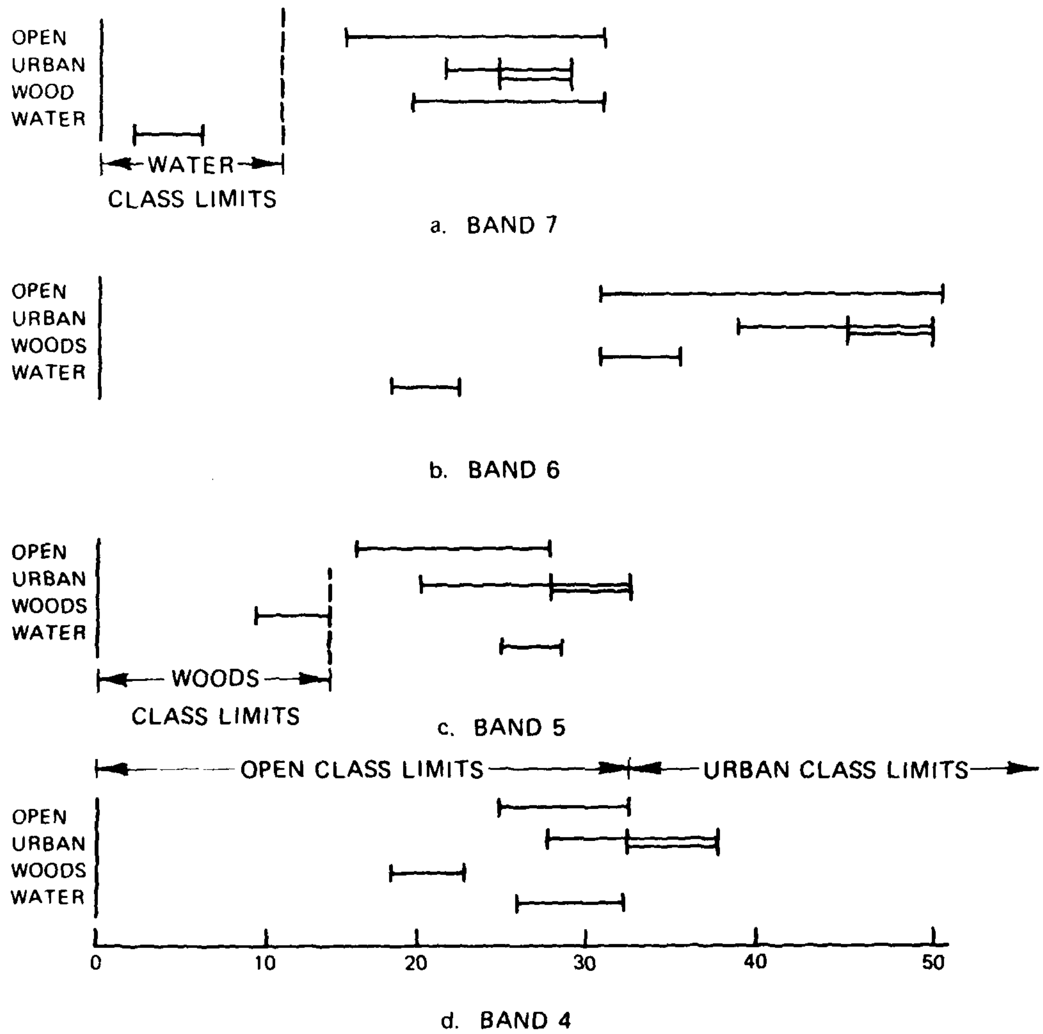


Figure 10. Range of reflectance by terrain class for each band, 1 October 1972

31. The following ranges were accepted as the limits for land-use classes.

	Band 4	Band 5	Band 6	Band 7
Water	0-127	0-127	0-127	0-11
Urban	33-127	17-127	0-127	8-63
Woods	0-127	0-14	0-127	8-63
Open Space	0-32	15-127	0-127	8-63

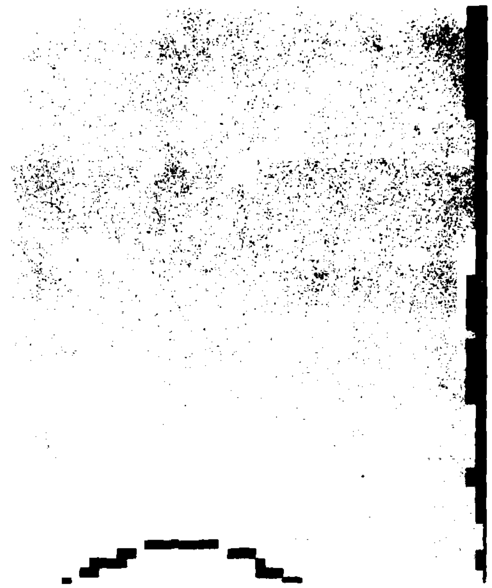
Note: Port Allen Vicinity Classification, Landsat 1070-16073, October 1972.

These class ranges were used to test each pixel in the Port Allen site in an automated procedure. When a pixel was within the class limits in all four bands, it was assigned that class code. When all pixels had been tested and recorded on tape, the tape was used to drive a film writer to produce a unique shade of gray for each class, making a picture of the land-use classes in the site. Figure 11 is such a picture of Port Allen for water, forest, and other classes. Figure 11a and 11b were classified with 100-m grids and 11c and 11d were classified with a smaller grid (50 m), which is nearer the original pixel size. Figure 12 separates the "other" class into the higher reflectance values of urban and open space in band 4.

32. This classification of 1972 data was used in the enlarged site to include Baton Rouge and vicinity. The three-class separation is shown in Figure 13 and the four-class separation in Figure 14.

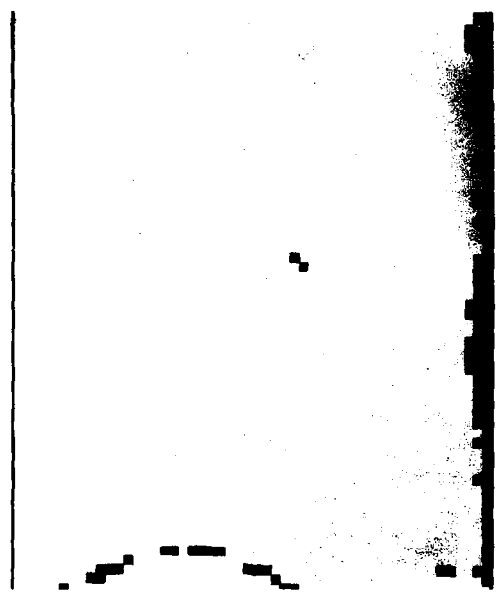
Classification Procedures of the Enlarged Site, Baton Rouge and Vicinity, 1977 Data

33. Aerial photography over the Baton Rouge area, flown in February 1974, was located at EROS. This was the most recent photography found for use in terrain sample location when this study was begun. Figure 15 shows the aerial photograph of the enlarged Baton Rouge site with the accordance transfer points identified: A is the midpoint of a bridge over a portion of a lake; B is the midpoint of a tributary entering the Mississippi River; and C is the midpoint of a tributary entering



a. Photography - February 1972

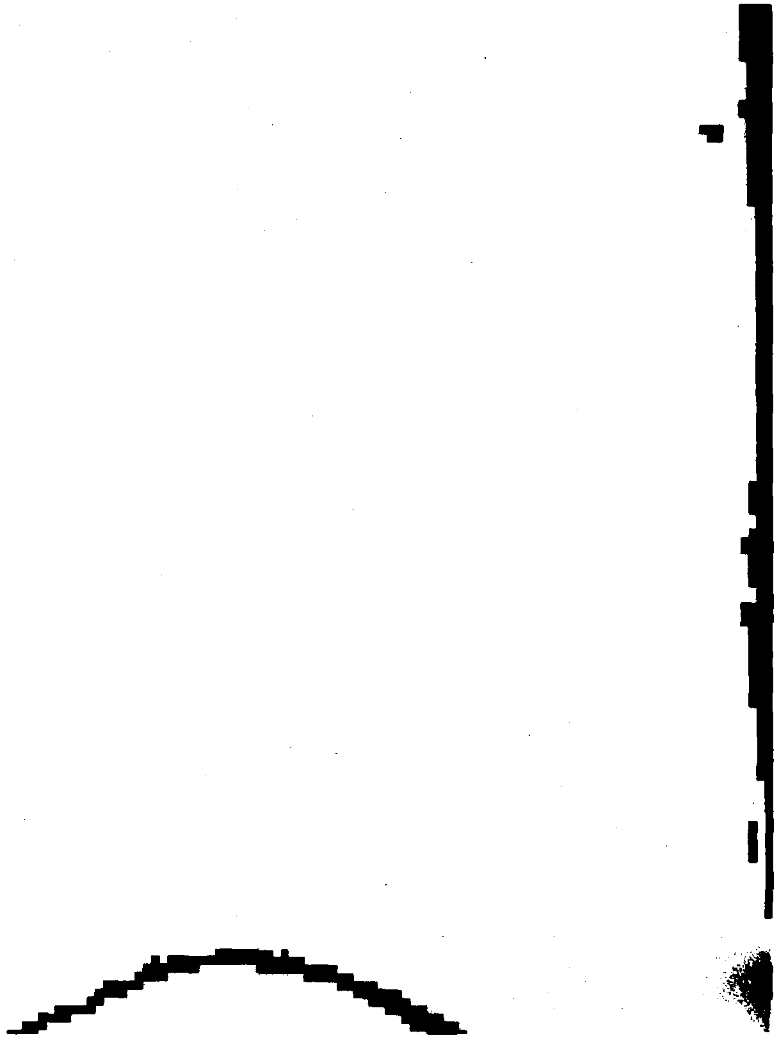
100-m grid



b. Landsat - October 1972

100-m grid

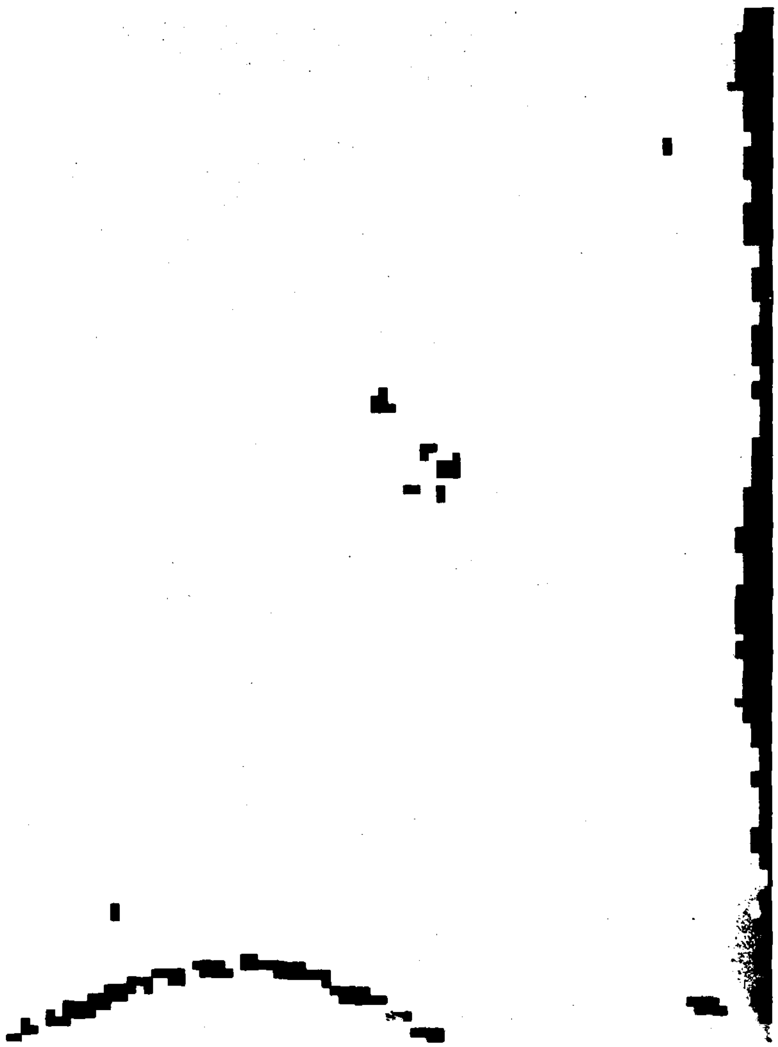
Figure 11. Water (black), woods (white), and other (light gray) land-use classes at the Port Allen site (Sheet 1 of 3)



c. Photography - February 1972

50-m grid

Figure 11. (Sheet 2 of 3)



d. Landsat - October 1972

50-m grid

Figure 11. (Sheet 3 of 3)

a. Photography - February 1972

100-m grid

b. Landsat - October 1972

100-m grid

Figure 12. Water (black), woods (white), open space (light gray), and urban (dark gray) land-use classes at the Port Allen site (Sheet 1 of 3)

c. Photography - February 1972

50-m grid

Figure 12. (Sheet 2 of 3)

d. Landsat - October 1972

50-m grid

Figure 12. (Sheet 3 of 3)

a. Photography - February 1972

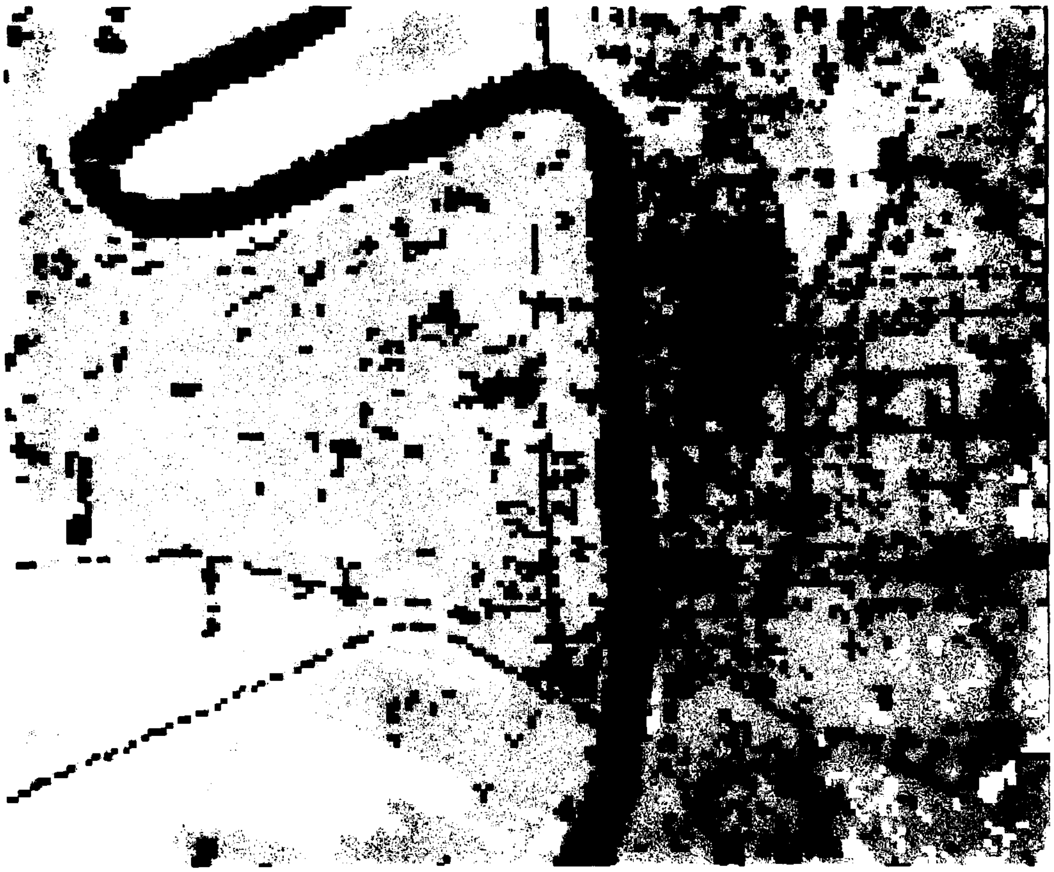
Figure 13. Water (black), woods (white), and other (gray) land-use classes at the Baton Rouge site (Continued)

b. Landsat - October 1972

Figure 13. (Concluded)

a. Photography - February 1972

Figure 14. Water (black), woods (white), open space (light gray), and urban (dark gray) land-use classes at the Baton Rouge site (Continued)



b. Landsat - October 1972

Figure 14. (Concluded)

Figure 15. Aerial photograph of the Baton Rouge study site, February 1974 (A, B, and C are transfer points; see paragraph 33)

the Intracoastal Waterway. Figure 16 shows the locations of land-use sample sites.

Land-use sample locations and data

34. Twenty-seven land-use sample sites were selected from the February 1974 aerial photograph (Figure 16). Four samples (1-4) were

Figure 16. Location of 27 land-use sample sites (1-27) at the Baton Rouge site, February 1974 photography

selected in what appeared to be heavily wooded areas; ten (5-14) were in the city of Baton Rouge; seven (15-21) were in open spaces, mostly sugar-cane fields; and six were in water (22-27). Equations 1 and 2 were used with the appropriate constants from Table 2 and distances of the sample locations from A (Figure 15) to determine the corresponding location (pixel and scan) in the Landsat data.

35. Reflectance values of the terrain samples and their eight surrounding terrain pixels were located in a digital listing of the Landsat data. The 3 by 3 arrays of data from sample 1 (woods) are listed below.

Band 4	Band 5	Band 6	Band 7
12 12 14	13 14 14	19 19 21	10 10 11
13 11 13	13 15 13	18 21 21	10 10 11
13 13 13	14 14 14	18 20 18	10 10 10

Spectral data analysis

36. Water and woods. Since the first objective of the study was to test the classification procedure to identify water and woods at the Baton Rouge site, only those terrain types were considered at this point. The mean and standard deviation were computed for each 3 by 3 data array to determine if the samples were representative of the terrain type from which they were selected on the aerial photo. The four samples from woods (1-4 in Table 6) had standard deviations less than 1.5. The water samples (22-27 in Table 6) contained two with deviations much higher, samples 24 and 26. Sample 24 was from a lake in Baton Rouge, and sample 26 was from the Intracoastal Waterway. Both of these water bodies are so narrow that the pixel values are mixtures of reflectance from water and nonwater. Having selected the samples in the widest parts of the water bodies, there seemed to be only two choices: delete the samples from consideration, or reduce the array by eliminating those pixels suspected of having reflectance mixed with that of surrounding terrain other than water. The samples were kept and band 7, which absorbs almost all reflectance from water, was analyzed. Those pixels with values greatly different from the other band 7 values were eliminated. The same

pixels were then eliminated from the other arrays as shown by the underlined elements in the following arrays:

Sample 24:

Band 4	Band 5	Band 6	Band 7
12 14 $\underline{14}$	12 12 $\underline{13}$	8 8 $\underline{15}$	1 1 $\underline{5}$
12 13 13	13 12 12	8 8 9	0 0 2
13 13 13	12 12 11	8 8 8	0 0 1

Sample 26:

Band 4	Band 5	Band 6	Band 7
17 15 $\underline{13}$	24 20 $\underline{15}$	18 18 $\underline{20}$	4 5 $\underline{9}$
17 17 $\underline{13}$	23 21 $\underline{15}$	20 16 $\underline{21}$	5 3 $\underline{10}$
$\underline{14}$ 17 $\underline{14}$	$\underline{17}$ 22 $\underline{16}$	$\underline{22}$ 16 $\underline{24}$	$\underline{9}$ 4 $\underline{10}$

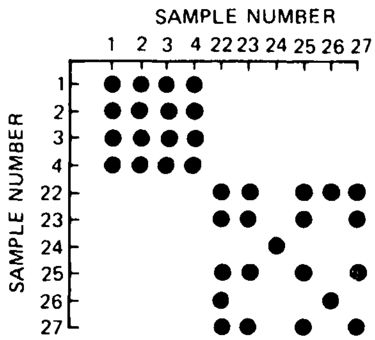
37. The means and standard deviations were recomputed for the two samples and listed in Table 6 as revisions. All water samples now met the 1.5 criterion for representativeness except sample 26, which had a standard deviation as high as 1.67. A screening window of 1.75 from the mean was accepted, and the range was computed for each band of all retained samples (Table 7). The values were rounded to the nearest integer to be compatible with the CCT's values.

38. Next, the ten woods and water samples were tested by the clustering program for inclusiveness of terrain type and exclusiveness between types. A diagonalization process* grouped those samples exhibiting similarity (i.e., samples with reflectance from all bands falling within the same variance windows). A similarity matrix plot was prepared by placing a black dot where the vertical and horizontal elements agreed. The matrix in Figure 17a showed that a variance of ± 1.75 would not form clusters either of all woods or of all water samples. The variance window was increased by increments of 0.25 until 2.25 included all woods samples in a cluster and all water samples except sample 24 in another

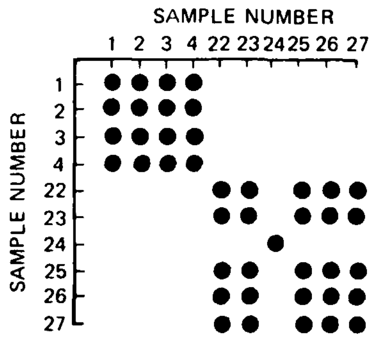
---

* Ibid.

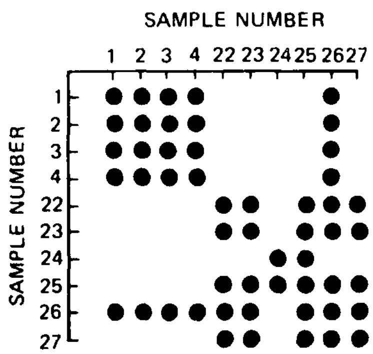
cluster (Figure 17b). The variance window was increased as before until 3.75 was reached (Figure 17c). Sample 24 was then similar to only one other water sample, and the two clusters were no longer exclusive. Sample 24 was shifted outside the water samples cluster and a diagonalization at variance 2.25 was produced as shown in Figure 17d. Since sample 24 did not encroach upon the characterization of woods, it was kept in the analysis as a water sample.



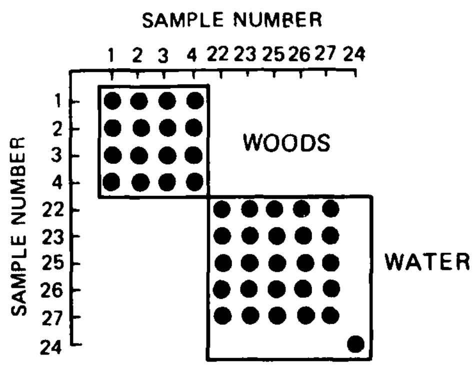
a. Similarity matrix
variance = 1.75



b. Similarity matrix
variance = 2.25



c. Similarity matrix
variance = 3.75



d. Diagonalization by cluster
variance = 2.25

Figure 17. Clustering and diagonalizing of wood and water samples, Landsat 1977 data

39. The variance windows of each sample were revised to ±2.25 and new class variances were determined (Table 7). It can be seen that the two classes can be separated from each other in band 7; in fact, none of the samples except water in Table 6 have reflectance values in the 0 to 7 range. Reflectance values in band 7 from 0 to 7 characterize water and from 8 to 63 characterize nonwater. It appears that woods can be discriminated from other nonwater pixels by band 5 with a class window of 12 to 16. A check of all sites in Table 6 shows no site other than woods or water with values below 16 for band 5. Urban sample 10 has a mean of 15, but it is a sample from woods within the urban area. By stretching all class ranges to be inclusive in order to classify all pixels, the following classification was developed for the Baton Rouge site and a land-use map produced (Figure 18). A visual comparison of

	Band 4	Band 5	Band 6	Band 7
Water	0-127	0-127	0-127	0-7
Woods	0-127	0-16	0-127	8-63
Nonwater Nonwoods	0-127	17-127	0-127	8-63

Figure 18 with Figure 16 indicates that a good separation of water and woods from each other and from other land uses was accomplished. A more complete comparison will be made later in Part III.

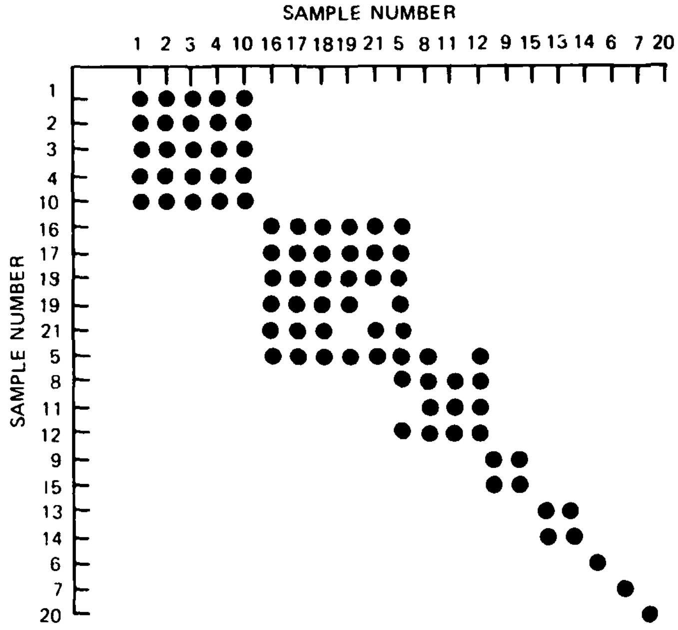
40. Urban and open areas. Another objective of this study was to explore the possibility of adding urban and open areas to the classification procedure. Delineating urban areas is difficult because the reflectance from such areas is not unique but resembles that of other land-use types in a varied array over the urban area. Samples 5-21 in Table 6 are from a variety of land-use types in Baton Rouge and from open fields. It can be seen immediately that a screening window of 1.5 will not work and increasing the window to 3.0 will eliminate almost half of samples 5-21. A review of the reflectance data from Baton Rouge indicated that it would be almost impossible to get homogeneous 3- by 3-reflectance samples from urban areas. Table 8 shows 7 by 7 arrays of pixels from an area in Baton Rouge. The values are almost a checkerboard

Figure 18. Classification of water (black), woods (gray), and other (white) land-use classes at the Baton Rouge site, 1977

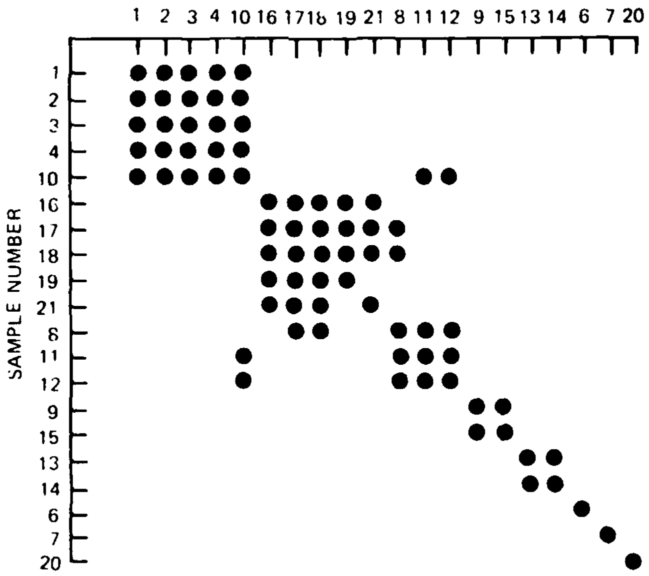
of high and low values. This condition appeared to be consistent over the whole city area. High and low variance was also observed in the data from fields where bare, vegetated, wet, and dry areas were intermixed.

41. Ignoring the screening window, a clustering procedure was begun with all samples except water. Water was not included because it can be discriminated from all other samples by band 7. With a variance of 1.75 (Figure 19a), a good separation could be seen of woods (samples 1-4) from open (16-21) samples. There seemed to be some grouping of the various urban samples. Sample 5 showed similarity to both open space and to urban samples; therefore, it was eliminated. The variance was extended to 2.00, and the clusters began to lose their exclusiveness (Figure 19b). Sample 10 showed a similarity with woods and not urban. This could be expected since it was a sample from woods in the urban area. For fear of distorting the classification for woods, it was eliminated from the procedure. Samples 9 and 15 showed similarity to each other but to neither of the types from which they were drawn, urban and open, respectively. They were both eliminated, and the surviving samples are shown in a diagonalized cluster array with a variance of 1.75 in Figure 20.

42. The surviving samples with variance windows of 1.75 are listed in Table 9 with the class ranges. These ranges were plotted (Figure 21) to determine unique ranges for urban and open space to be added to the successful class ranges of woods and water. Again there seemed to be no way to separate open from urban except for those urban samples with very high reflectance such as samples 6, 7, 13, and 14 (industrial areas, large flat roofs, parking lots, and wide concrete thoroughfares). Since these terrain types are found in urban areas and not in open spaces such as fields, they could be the "locators" for the urban areas and perhaps even define, to some degree, the extent or borders of the urban areas. In the spaces between the high reflectance pixels there are many pixels with varying lower reflectance that complete the urban area. The class range for urban was then redefined as high reflectance in band 4 (shown by * in Table 9 and indicated by a double bar in Figure 21). Band 4



a. VARIANCE WINDOW - 1.75



b. VARIANCE WINDOW - 2.00

Figure 19. Clusters with variance windows of 1.75 and 2.00

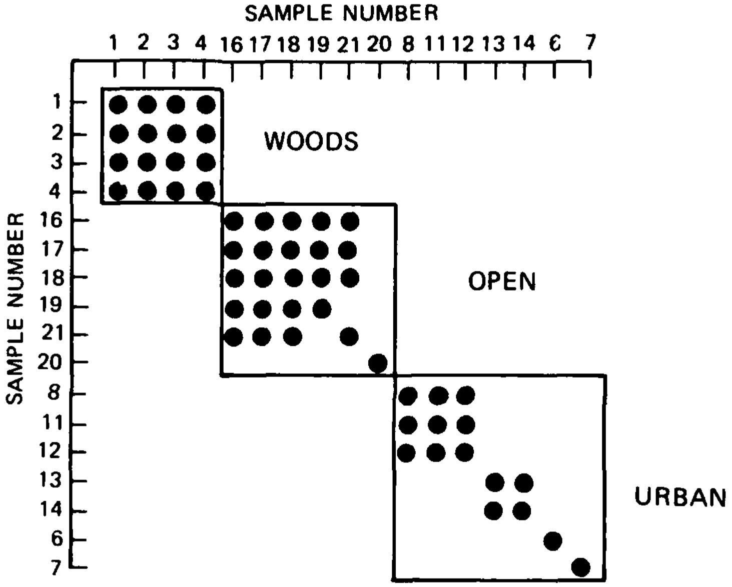


Figure 20. Clustering of samples from Baton Rouge site with a variance window of 1.75

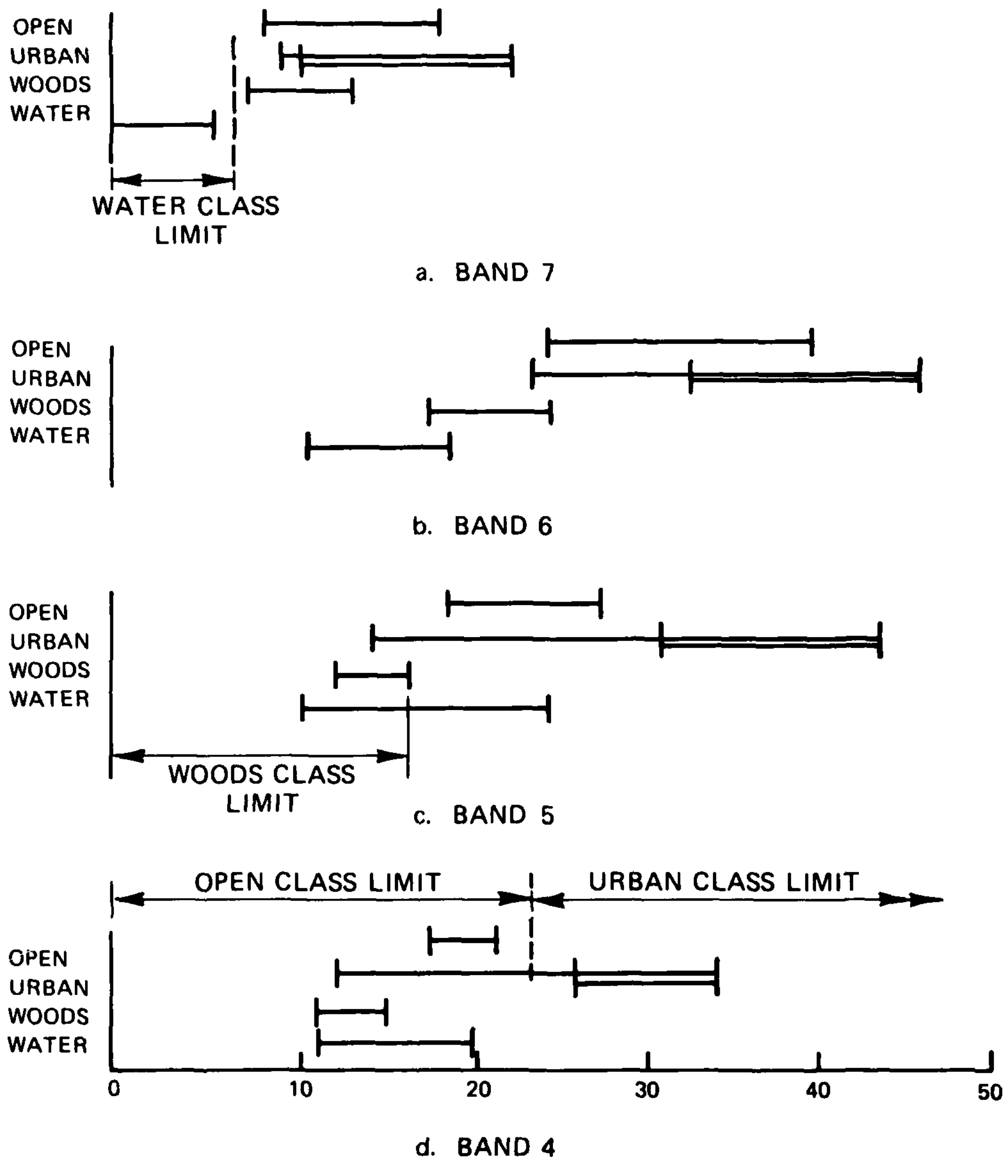


Figure 21. February 1977 Landsat range of reflectance by terrain class, Baton Rouge site. (Double bar defines the accepted urban range)

shows the widest separation of open and the new urban range, so the value halfway between them rounded to the nearest integer (23 or 24) could be accepted as the lower urban class limit. After several runs, 23 was kept as the lower urban limit.

43. By increasing the limits to include all pixels, the classification becomes:

	Band 4	Band 5	Band 6	Band 7
Water	0-127	0-127	0-127	0-7
Urban	23-127	17-127	0-127	8-63
Woods	0-127	0-16	0-127	8-63
Open	0-22	17-127	0-127	8-63

Each pixel in the data array was tested for compliance with land-use windows in order (first, water; and then urban, woods, and open space) until it qualified as one of the classes. When a pixel qualified for a land-use class, no more testing was performed on it and the next pixel in the scan was tested and so on to the next scan until all had been tested. All pixels will fall within some class since the classification is inclusive.

44. Figure 22 shows the results of this classification. The green areas indicate woods; blue, water; yellow, open spaces; and red indicates high reflectance surfaces, most of which are located within urban areas. The high reflectance areas outside of urban areas are mostly from highways (especially intersections), oil fields and refineries, and clusters of buildings. Some red areas appear to be from sand (in the bend of the river in the top center of the image) and from highly reflecting areas in the open spaces, e.g., bare dry soil. These must be accepted as misclassifications of urban areas at present.

45. Figure 23 is a picture of the entire 1977 Landsat scene, 2768-15410, using the same classification as for the Baton Rouge area with the same color identifications. Part of Lake Pontchartrain is in the center of the east edge. The Mississippi River runs from top left to just below Pontchartrain on the right. The other large river, westward of the Mississippi, is the Atchafalaya. Water and woods are well

Figure 22. Landsat classification of Baton Rouge and vicinity with four land-use classes. Green areas indicate woods; blue, water; yellow, open spaces; and red, urban

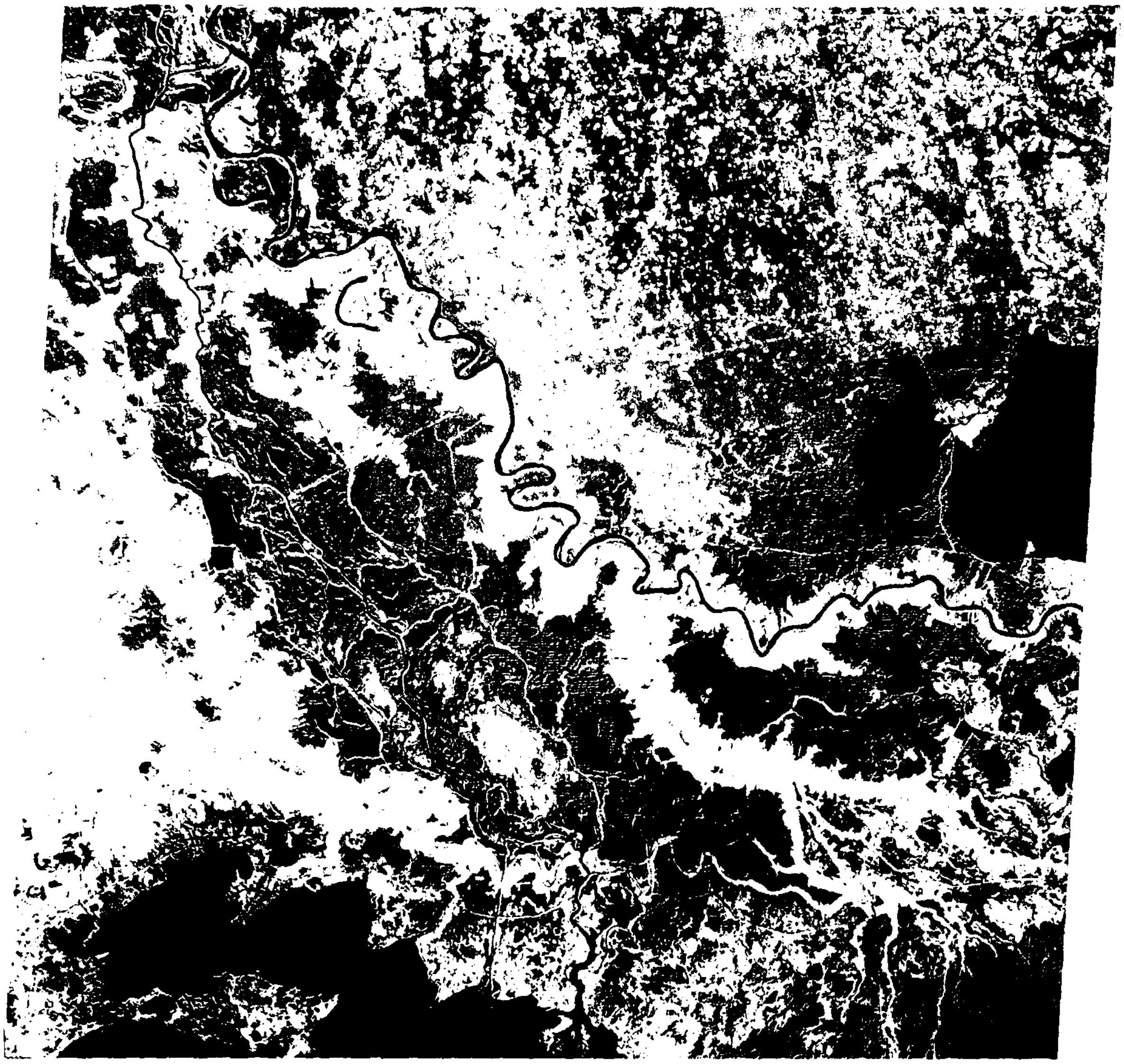


Figure 23. Classification of full scene Landsat 2768-15410 using classification for the Baton Rouge site. Green areas indicate woods; blue, water; yellow, open space; and red, urban

defined. The large Atchafalaya Basin shows almost entirely as water, woods, and a mixture of water and woods with very little open space. Open spaces are concentrated around the Mississippi River, other rivers, and highways. Clusters and strings of red fall where cities, communities, river banks (possibly due to sand), and other highly reflecting terrain are located.

Classification Without the Guidance of Land-Use Samples

46. Suppose that aerial photography or other terrain information were not available for guided classification. Some other technique would be needed for reflectance separation of terrain classes. A preliminary investigation was undertaken with the same Baton Rouge area Landsat data (28 February 1977) to find those pixel signatures that could be related to terrain classes. The classification procedure was modified to substitute a computer analysis for the aerial photography interpretation of terrain classes to identify a reflectance range for each band.

47. The computer analysis was made in the following steps:

a. Arrays of 3 by 3 pixels were examined by the computer for similarity with a given standard deviation of 1.5. The standard deviation is a variable input to the automated procedure.

b. The means of those arrays with similarity were listed by homogeneity within each band beginning with band 7 and proceeding to band 4.

c. A frequency list was compiled of signatures composed of array means.

d. A cluster analysis was performed on those signatures occurring five or more times.

e. The diagonalization procedure was applied to the developed clusters.

f. Class ranges were established for unique clusters.

g. A classification picture was written and printed for the Baton Rouge site.

48. The Baton Rouge site contained 14,338 arrays (320 scans of 403 pixels each) of 3 by 3 pixels each. Of these, 4062 showed

similarity with a 1.5 standard deviation. Higher standard deviations could have been selected, which would have been more inclusive, or lower for more restriction. An example of the homogeneity listing is presented in Table 10, and an example of the frequency listing is presented in Table 11. These are partial listings. As can be seen in Table 10, first the signatures with band 7 mean reflectances from lowest to highest were listed, with sorting continued in each band of the signature. Band 6 values were sorted from lowest to highest in each unique reflectance value of band 7, and so on until all signatures with homogeneity had been listed. In Table 11, the highest number of any one signature is 290 for signatures 13, 15, 21, and 11 (reflectance for bands 4, 5, 6, and 7, respectively).

49. One hundred twenty-two of the signatures occurred five times or more. The standard deviation was reduced to 1.3 and 84 signatures were found occurring five or more times. Since 1.3 may not have been out of the noise level, the signatures from the 1.5 standard deviation analysis were used in the clustering procedure.

50. To qualify as a member of a cluster, a signature must exhibit similarity in all bands to every other member in the cluster. Two of the one hundred twenty-two could not qualify in this requirement and were eliminated. Ten separations were found with the clustering procedures. The ranges, lowest to the highest for each band in a cluster, are shown below:

		Range of Reflectance Values			
Cluster	Number of Signatures	Band 4	Band 5	Band 6	Band 7
1	26	17-19	20-22	12-14	1-2
2	36	12-14	14-16	19-22	10-12
3	10	12-14	13-16	19-21	9-11
4	18	13-15	14-16	23-25	11-12
5	14	19-21	25-27	28-30	11-13
6	6	19-20	23-25	27-29	11-12
7	4	14-15	17	23-25	11-13
8	4	12-13	13-14	17-19	8-10
9	1	21	27	31	13
10	1	17	21	25	11

51. From this point, classification was no longer unguided. Prior knowledge of reflectance values associated with land-use classes and the gray-scale pictures of each band (Figure 6) were used to identify clusters by land-use classes. Low values in band 7 had been used to separate water from other reflectance values; therefore, cluster 1 was identified as water. Low values in band 5 had been used to successfully separate woods from other reflectance in that band;* therefore, clusters 2, 3, 4, and 8 were combined for woods identification:

	Band 4	Band 5	Band 6	Band 7	Cluster
Water	17-19	20-22	12-14	1-2	1
Woods	12-15	13-16	17-25	8-12	2,3,4,8

52. A look at Figure 6 indicates that band 4 shows the greatest contrast between pixels in Baton Rouge and those in open areas. A histogram of reflectance values indicated that the similarity signatures did not include the highest reflectance values. Apparently the 3 by 3 matrices containing the high values of band 4 did not meet the homogeneity criterion. Upon examination of the data, this proved to be true. This was understandable since it is probable that the higher values came from highly reflective surfaces such as buildings, hard-surfaced highways, large flat rooftops, and parking areas. These surfaces are complex in arrangement and varying in slope and proximity, i.e., not in a homogeneous arrangement such as water or woods. The remaining similarity clusters, with the lower values in band 4, should be representative of open spaces such as space occupied by sugarcane fields, pastures, and croplands; in fact, it was thought they must be associated with everything not water, wood, or urban. Combining clusters 5, 6, 7, 9, and 10 into one range and assigning the higher reflectance values in band 4 to urban, the following associations were made:

	Band 4	Band 5	Band 6	Band 7
Open	14-21	17-27	23-31	11-13
Urban	22-127	0-127	0-127	0-63

---

* Ibid.

53. Figure 24 shows plots of the cluster groupings and reflectance values from paragraph 52. Another consideration was given to those higher reflectance values not appearing in the similarity signatures. It was supposed that older residential areas in Baton Rouge would have trees, which would cause pixels from those areas to be classed as woods rather than urban, but would have higher reflectance in bands 4 and 6. The following separation was made: if pixels classed as woods by band 5 had higher band 6 reflectance than those included in the list of homogeneous signatures, then they were classed as other urban.

54. When the range limits were increased to be inclusive of all pixels, the following classification was made:

	Band 4	Band 5	Band 6	Band 7
Water	0-127	0-127	0-127	0-7
Woods	0-127	0-16	0-25	8-63
Other (urban)	0-127	0-16	26-127	8-63
Open	0-21	17-127	0-127	8-63
Urban	22-127	17-127	0-127	8-63

Figure 25 shows the resulting classification. While a close look at Figure 25 shows some of the other urban class in the urban area, more of it appears in what should have been open space. No further study was made in this direction; however, a comparison of Figure 25 with Figure 15, the guided classification, indicates that water and woods can be classified very well without guidance from terrain samples.

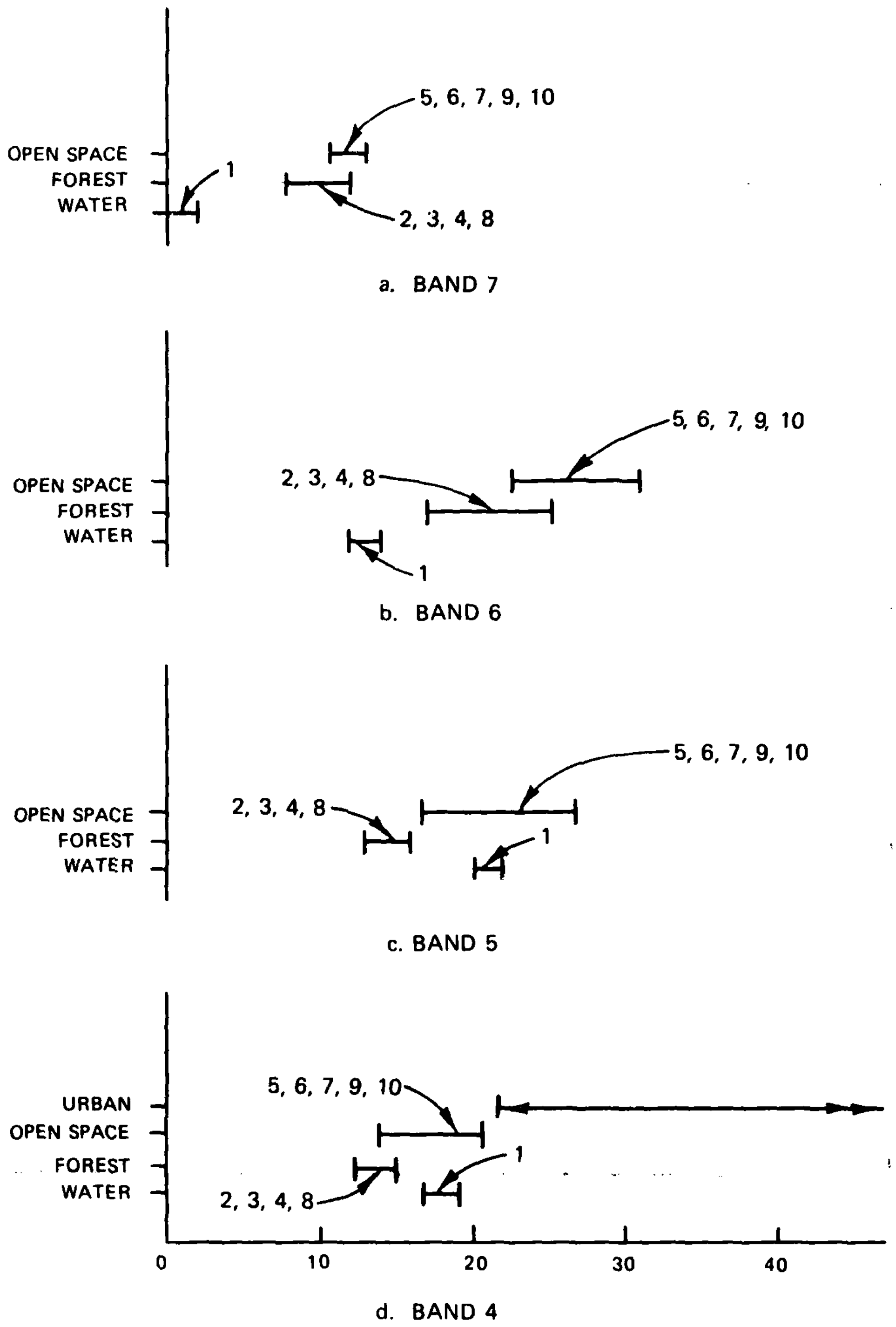


Figure 24. Reflectance ranges grouped from unguided cluster analysis

Figure 25. Baton Rouge area classified without sample guidance, 2768-15410. Green areas indicate woods; blue, water; yellow, open space; brown, other urban; and red, urban

PART III: EVALUATION

Evaluation Procedure

55. Evaluations of land-use classification from Landsat data were made to test the procedure (in areas other than the Satartia test site used by Struve, Grabau, and West (1977b)*) for classifying water, forested, and other land-use classes. The evaluation was made by comparing the Landsat classified maps to photo-interpreted land-use maps of the same site area. Both maps were rectified to UTM coordinates on the same scale topographic maps and gridded to the same cell size for a comparison of areas in each land-use class.

Photo-interpreted land-use maps (UTM)

56. Land-use classes (water, woods, urban, and open space) were manually interpreted from aerial photography by outlining the areas on transparent overlays inside a rectangular border (area of interest). The corners of the area of interest were identified by UTM coordinates in thousands of metres. The class areas (patches) on the overlay were then digitized; i.e., their borders were defined in terms of digitizer coordinates that were referenced to the UTM coordinates of the upper left corner. The digitized data were stored on magnetic tape and later fed into a computer program that transposed the patch descriptive data into a rectangular grid system by coding each space in the grid system with the land-use code of the patch containing the space. The grid size, an option in the computer program, was chosen as 100 by 100 m for comparison with the Landsat classification maps. The gridded data were stored on magnetic tape and fed into the film writer to produce land-use maps (Figures 13a, 14a).

Landsat land-use maps (UTM)

57. A Landsat land-use map for the same area of interest (described by the same UTM corner coordinates) was produced by the following steps.

---

* Ibid.

a. Classification of the full Landsat scene.

(1) A computer program was developed to join the WES Landsat tapes (west and east halves) of the Landsat scene.

(2) The full Landsat scene was classified using class reflectance ranges as discussed in Part II, e.g., Port Allen site (paragraph 31).

b. Rectification of the site land-use map to UTM coordinates.

(1) Five clearly defined points (e.g. intersections of major highways) in the vicinity of the selected site were located on a topographic map and identified by their UTM coordinates.

(2) The corresponding points were located on the Landsat band 5 image, and 50- by 50-pixel data arrays centered on each point were extracted from the reflectance data.

(3) Using the high reflectance values in band 5 to identify the transfer points, the pixel and scan of each of the five points were determined.

(4) The two sets of identifying data, UTM coordinates and corresponding pixels and scans, were fed into a computer program that computed the angle of rotation, the width and length of the transposed pixel, and the UTM coordinates of the first pixel and scan of the transposed map. These constants were used to transpose any array of extracted data in the locale of these transfer points to UTM coordinates. This resampling technique was applied to unstretched classified data, i.e., the third and twentieth repeated scans which were used for geometric accordance (paragraph 26) were removed. The resampling procedure also includes the option to change the pixel size in the transposed map to selected width and length. In this study, 100- by 100-m pixels were selected and the transposed map data stored on magnetic tape.

Accordance of Landsat map
with photo-interpreted map

58. The final maps were then prepared with the photo-interpreted map as the base map or standard for comparison. The following steps were used:

a. The Landsat classified data, transposed to UTM coordinates, were overlaid by the data of the aerial photograph land-use map, which was used as a mask to bring the two maps into area agreement.

b. The resulting Landsat classified data were fed into the film writer and a land-use, gray-shaded map was written.

A site in the Atchafalaya Basin (Figure 26) was classified and rectified by this procedure (Figure 27). Figure 28 is a photo-interpreted land-use map of the same area of interest. The two maps now covered the same area with the same scale and were rectified to the same UTM coordinates.

Comparison of Landsat map with photo-interpreted map by total area

59. A computer program was written to sum the number of pixels (grid spaces) for each class in each map, to convert this sum to acreage or other area measurement, and to compute the percent of each class in the total site. The percent of the Landsat classes in the total site were compared to those derived from the photo-interpreted procedure, which were accepted as the true percents. The difference in percents expresses the error in classification by Landsat. Table 12 shows the results of this procedure for the Port Allen and Baton Rouge sites and for Satartia, the site used in the development of the classification procedure described by Struve, Grabau, and West (1977b).*

Automated comparison of land-use maps

60. The comparison of percent area of the site is meaningful but may lead to false conclusions in classification accuracy. The total area by class may agree, but the positions of like classified grid spaces may be drastically different. A new program was used to compare not only the total number of correctly identified grid spaces (area), but also to compare the two maps grid-by-grid in the area of interest common to both maps. The program will accept maps of different size, orientation, and grid-space dimensions. The required input to the program consists of the two data arrays, a set of control points describing common ground surface points in terms of each map's x- and y-distances, land-use codes on each map, patch numbers on the standard map, and desired land-use code comparisons. In this study, the aerial photography maps were the accepted standards.

61. The output of the automated procedure is a series of tables

---

* Ibid.

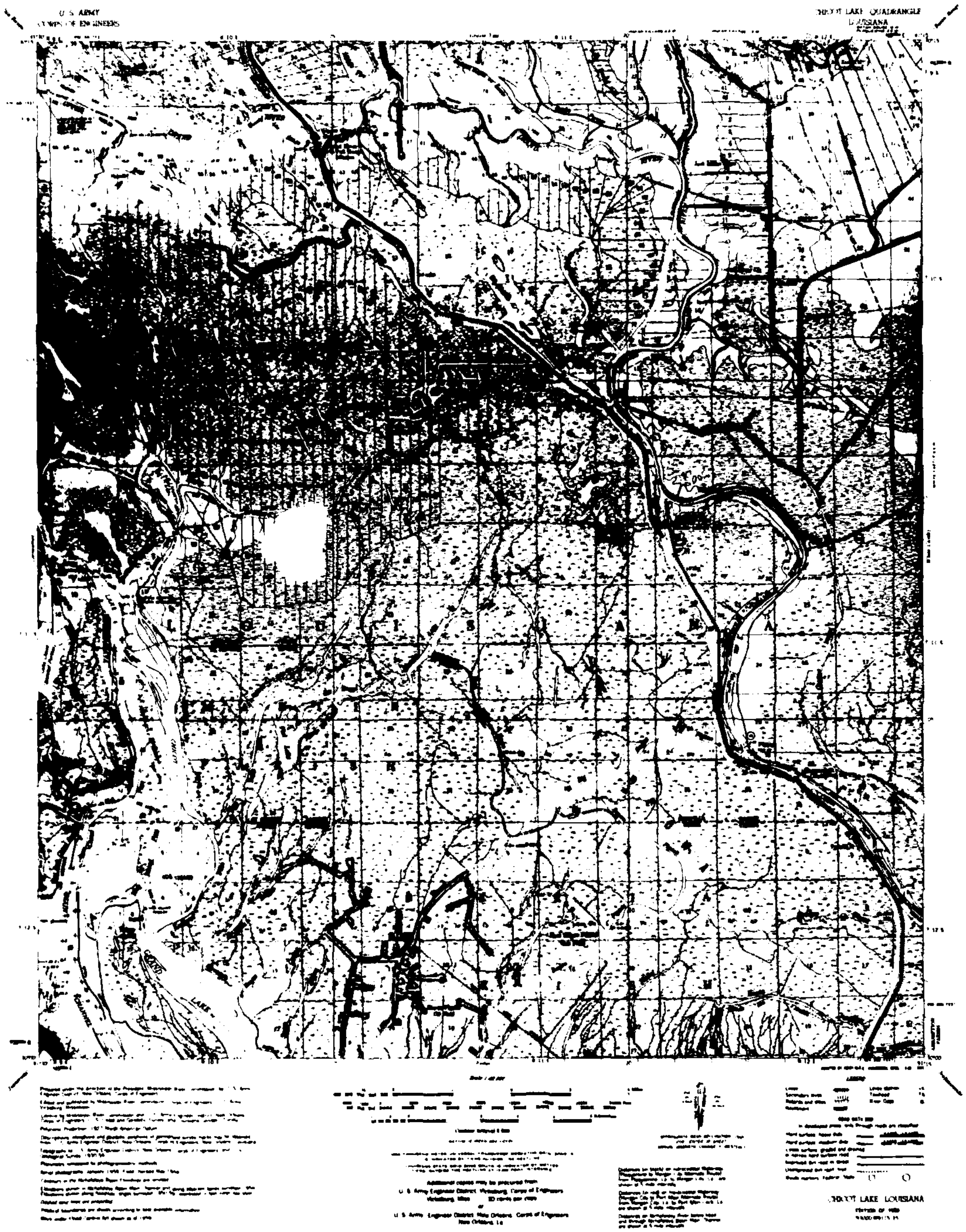


Figure 26. Reduced Chicot Lake quadrangle sheet containing a site in the Atchafalaya Basin

Figure 27. Portion of Atchafalaya Basin classified using February 1977 data. (Black represents water; white, forest; and gray, open)

Figure 28. Portion of Atchafalaya Basin classified by manual interpretation of aerial photography. (Black represents water; white, forest; and gray, open)

listing the control point locations, the comparison of x- and y-coordinates of the two maps, the number of correctly classified grid spaces, the land-use classes incorrectly identified, and the percent of correctly and incorrectly identified spaces by total areas, by patch areas, and by class.

62. Table 13 is an example of the control points of a standard map and another map (Landsat) and the ratio of the x- and y-coordinates of the two maps. In this example, the Landsat map area of interest (171 by 141 grid spaces) was a part of a larger (311 by 331 grid spaces) aerial photography map.

63. Table 14 lists the differences between the projected and actual distances of the Landsat control points. Points 5 and 6 are as much as four or five grid spaces different from other points. The greatest misclassifications will likely occur in the map areas of these control points.

64. Table 15 lists the number of grid spaces in the Landsat map that were correctly identified by land-use class. Also shown are the classes assigned to the incorrectly identified grid spaces, e.g., of the 2307 water grid spaces on the standard map, 1751 were classed correctly by class and position; 94 were classed as woods; 404 as open space; and 58 as urban. In addition to the 1751 correctly identified water grid spaces, Landsat incorrectly identified 116 woods, 48 open space, and 20 urban spaces as water.

65. Figures 29-31 illustrate the comparison technique. Patches including only one land-use class are manually drawn with their class codes on an overlay to the photo (Figure 29a). The boundaries of the patches are identified in terms of map and UTM coordinates by a semi-automated digitizing process and automatically stored on magnetic tape. The digitized information is used in an automated gridding procedure (Figure 29b) to produce a map (Figure 29c). The transformation of the Landsat map for geometric accordance with the standard map is performed sequentially for each grid space in the standard map. The class code of the corresponding Landsat grid space is transposed to a new map coincident in position with the standard map. The following steps are

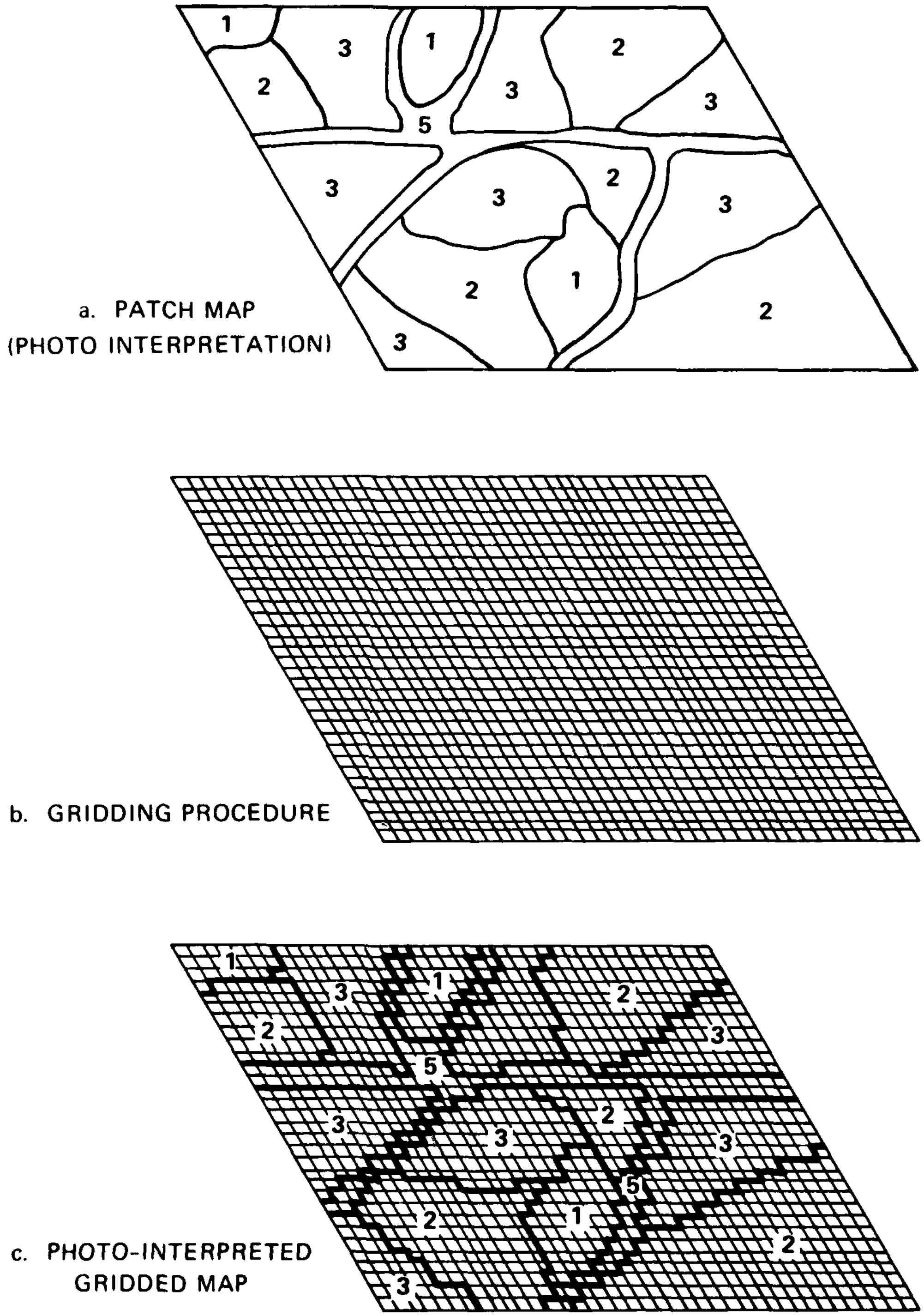


Figure 29. Conversion of aerial photography to a land-use gridded map

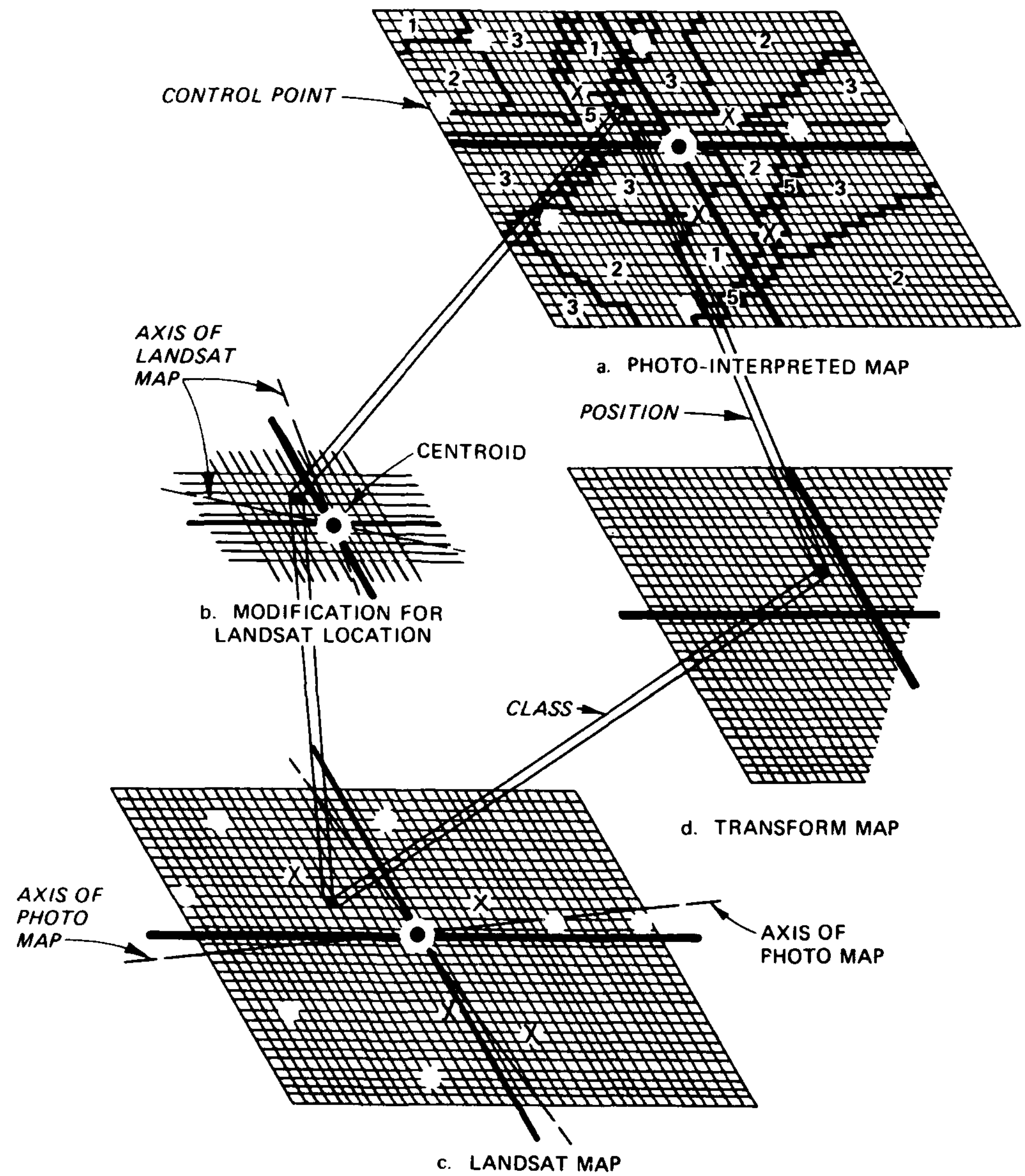


Figure 30. Construction of the transform map

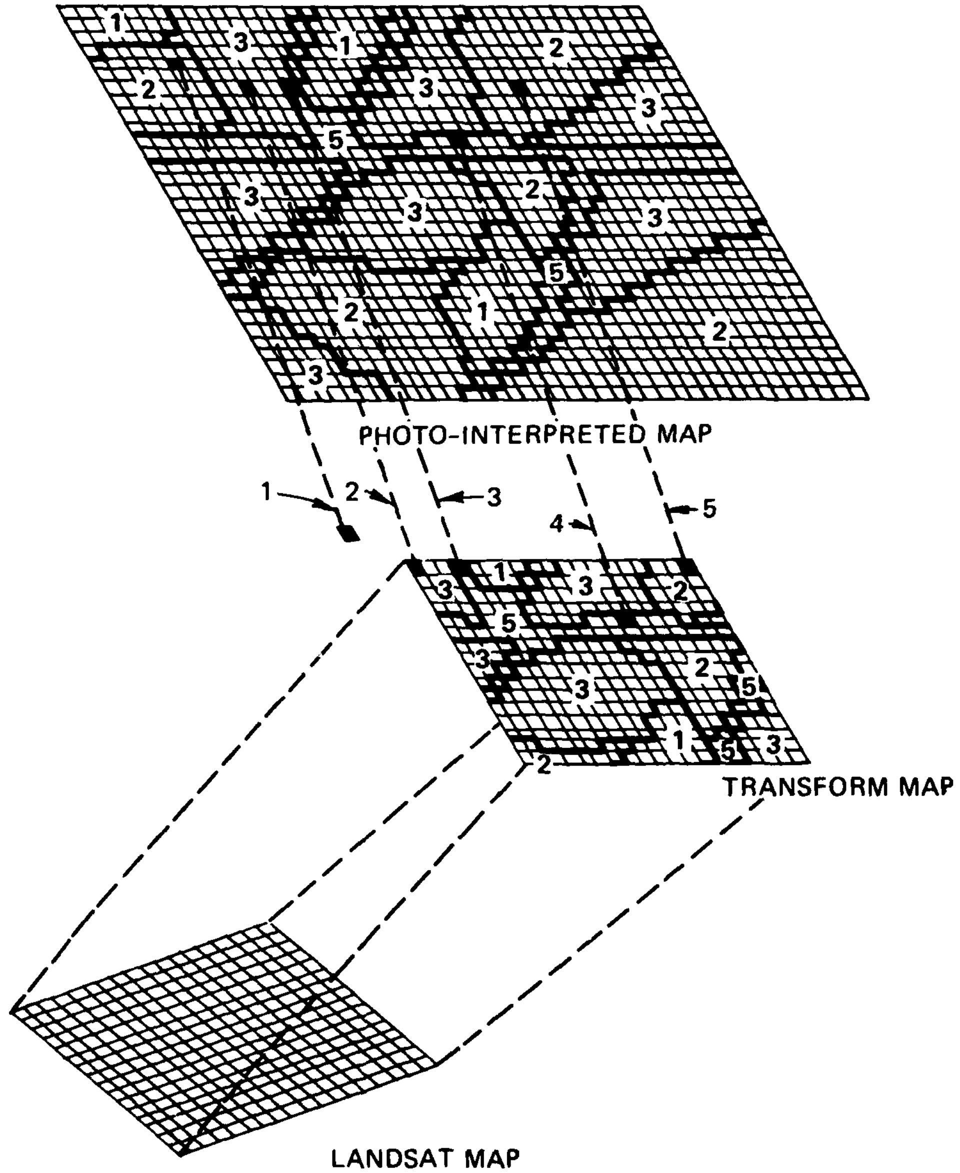


Figure 31. Comparison of Landsat land use with photo interpretation, grid space by grid space

performed in the transformation (Figure 30):

- a. The control points are checked for the nearest four that lie in different quadrants relative to the grid space (Figure 30a).
- b. The centroid of the four control points is located in both standard and Landsat maps (Figures 30b and c).
- c. The distance and direction of the grid space from the centroid in the standard map are modified by a weighted square of the distance and the difference in scale and rotation of the Landsat map (Figure 30b).
- d. The modified distance and direction are used to locate the corresponding grid space in the Landsat map (Figure 30c).
- e. The class code of the Landsat grid space is placed in the grid space of the transform map that is coincident with the grid space of the standard map (Figure 30d).
- f. The above procedure is repeated for all grid spaces in the area of interest of the standard map.

66. The class of each grid space in the standard map is compared to the class of the corresponding grid space in the transform map (Figure 31). Those spaces in either map not coincident (e.g., line 1 in Figure 31) are excluded from the summing activity. Lines 2, 3, and 5 join coincident spaces with the same classes in both maps and will be included in the sum of the correctly identified classes in the patch and in the map. Line 4 joins coincident spaces with different classes and will be summed accordingly, i.e., summed as incorrect by class in the patch and in the map.

67. Table 16 is a partial output listing of the number of spaces in the standard map patches, the correct class, and classes on the Landsat map for the corresponding patch. Note that some patch numbers are missing from the list. These were one-space patches and were eliminated from the correlation procedure by an island-removal program for removal of spurious data. The program tests the eight pixels surrounding the isolated space and assigns it to the class most frequently occurring among the eight. A test case (3 classes) of before and after island removal showed only a small change in the summary results, from 91.696 percent to 92.108 percent for a gain of 0.512 percent correctly classified.

68. Table 17 is the output summary of the class correlation

patch-by-patch of the two maps. The list is arranged by sequence of the class codes and by size within the class; e.g., water (code 1) is listed first with patch 13 first within the class (1559 grid spaces). The total area (standard map), the number of correct and incorrect classifications, and the percent of patch and percent of map are shown for correct and incorrect classifications.

Order in which
evaluations were made

69. The October 1975 Satartia site results* were used as a reference for the success of classification by area in this study. These were from a three-class separation: water, woods, and the remainder of the site in the class called "other." The first evaluations were made for the Port Allen and Baton Rouge three-class separations compared to the Satartia site results for area percentage. Next, an evaluation was made of the three-class separations using area percentage and position as criteria. Since this kind of result was not made by Struve, Grabau, and West (1977b),* only the comparison to the photo-interpreted maps was available as a standard. Following the evaluations of the three-class separations, the four-class separation evaluations were made by area percentage and position.

70. Other evaluations were then made of (a) the difference in class ranges of reflectance, (b) the effect of shape and size of class patches, (c) the orientation of patches to the scanning of Landsat sensors, (d) the limitations of photo interpretation as a standard, (e) the limitations of the Landsat classification and change detection, and (f) the use of Landsat to identify urban areas.

Water and Woods Classification Comparisons

71. The comparisons by area of the Landsat classifications with photo interpretation classifications for three classes are given in Table 12 for Satartia and Baton Rouge sites. The two sites are similar

---

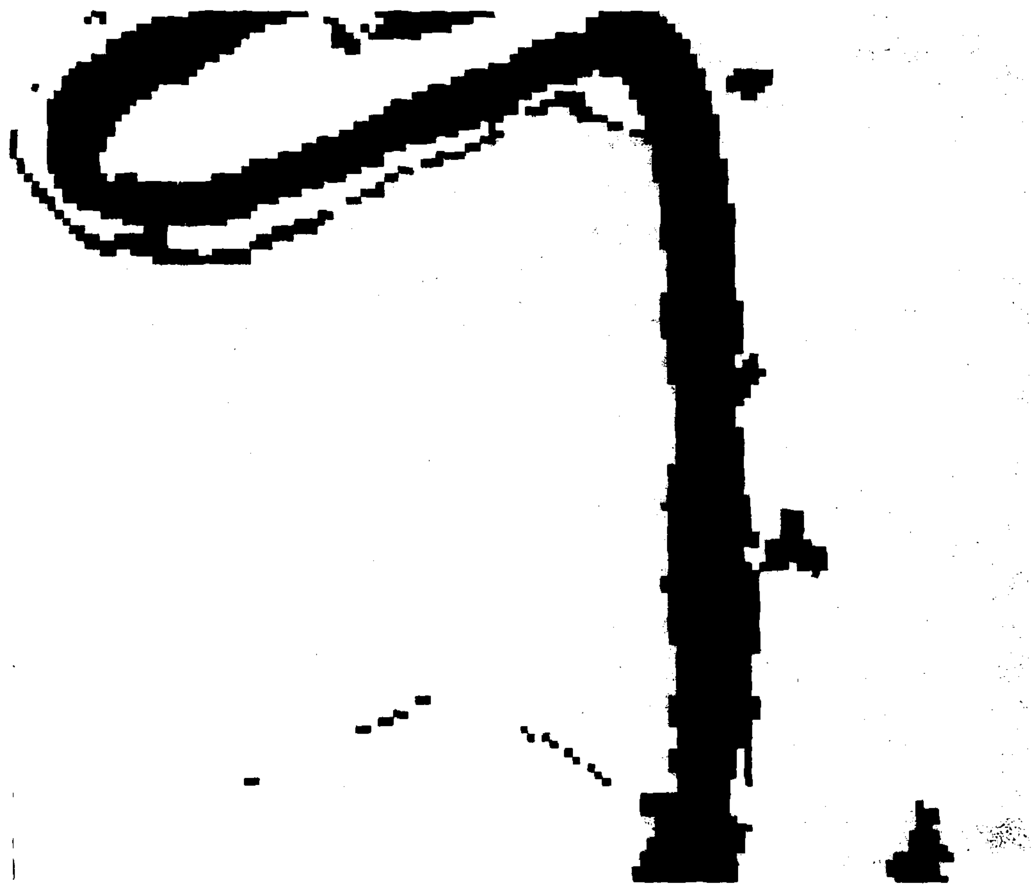
* Ibid.

in climate, soil, and physiography. They both lie in the flat, low-lying floodplain of the Mississippi River with soil formations of the Pleistocene age. The summers are long and hot. Precipitation is the heaviest in the winter and spring months, lighter in the summer months, with an average annual precipitation of 53 and 54 in., respectively, for Satartia and Baton Rouge. Satartia lies approximately 2 deg almost due north of Baton Rouge. Cotton and soybeans are major crops in the vicinity of Satartia. The major crop in the Baton Rouge vicinity is sugarcane. The major difference in land use of the two areas is the large urban area in the Baton Rouge site. With the similarity of the two sites, a close comparison in classification was expected for the data collected in October for both sites. All of the guided classifications were within 2.2 percent of the Satartia results. The classification results of the 1972, 50-m grid for Port Allen and the 100-m grid for Baton Rouge were closer to the photo interpretation than Satartia as shown in Tables 12 and 18.

72. Comparison by position decreases the percentage of correct classification by 6 to 7 percent for 1972 and by 9.2 percent for 1977 (Table 19). Pictures of the Landsat classification and the photo-interpreted standard maps for the Port Allen and Baton Rouge sites are shown in Figures 11, 13, and 32. The map data for these pictures were used in the comparison program giving the three class comparisons of Table 19 and the following results:

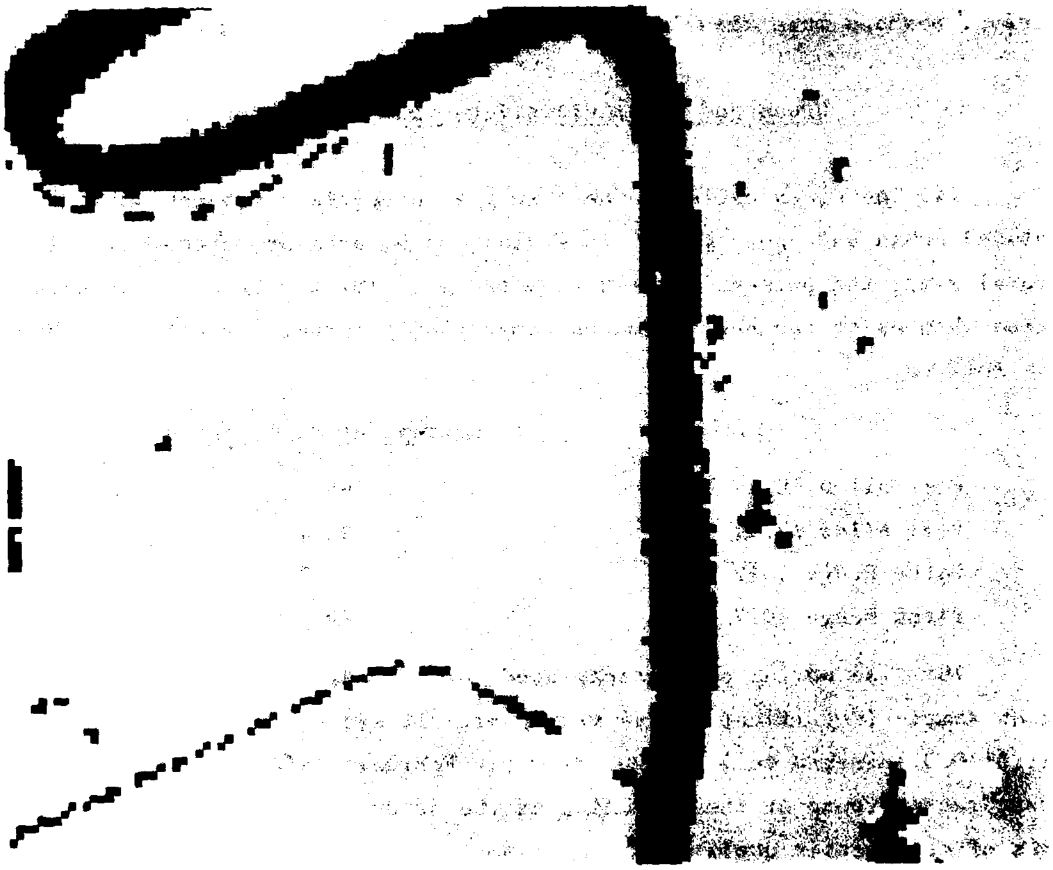
	Percent of Site Correct
Port Allen 1972, 100 m	91.7
Port Allen 1972, 50 m	91.5
Baton Rouge 1972	92.1
Baton Rouge 1977	85.9

73. Some thought should be given to the selection of a standard by which the Landsat classification is measured. Difficulty exists in obtaining photography taken at the proper time and of reliable quality; the alternative is to bear the expense of having photographic missions flown. Even with the best photography at the desired time, there are



a. Photography - October 1974

Figure 32. Water (black), woods (white), and other (gray) land-use classes at the Baton Rouge site (Continued)



b. Landsat - February 1977

Figure 32. (Concluded)

still other factors affecting its quality as a standard, such as the manual interpretation of land-use classes, the production of the class patch maps for the digitizing function, the digitizing itself (whether with a hand-held sensor or with an electronic scanner), the conversion of digitized data on tape to a machine-compatible format, and, finally, the interpretation of the digitized data to an array representing the land surface by a gridding procedure. There are many places for human error, perhaps more than in the classification of the Landsat data.

Urban and Other Classification Comparisons

74. The class called "other" in the three-class separation included urban and open space. In evaluation by area as percent of the total site, the percent correct remained good for the three-class separation when using the new automated comparison program. Results are shown as follows:

	Percent of Site Correct
Port Allen 1972, 100 m	94.7
Port Allen 1972, 50 m	95.1
Baton Rouge 1972	84.7
Baton Rouge 1977	72.7

75. The aerial photography used for the 1977 Landsat classification sample identification was very poor. It was color infrared, 1:131,000 enlarged to 1:65,500, flown in February 1974, but it was the most recent found at the beginning of the study. The 1972 photography was of much better quality.

76. One of the biggest factors in the poor results of the four-class separation comparisons is the interpreter's criterion that industrial, business, and all residential areas (whether new or old) make up the urban class. The Landsat sensors record the reflectance as it is; an older residential area with a lot of trees would be classed as woods even though it is next to an industrial area. The photo interpreter calls it urban; Landsat classification did not make that interpretation.

The second biggest factor is probably the similarity of integrated reflectance from a mixture of entirely different land use. Many reflectance values in Baton Rouge from residential areas are from tree tops, rooftops, and paved streets. The resultant integration is reflectance higher than that from woods, lower than that from highways and buildings, but very like that of the integration of reflectance from sugarcane fields, bare ground, and a few farm buildings. This can be seen in the pictures of the aerial photography and Landsat classifications in Figures 12, 14, and 33 and by referring to Figures 2 and 7.

77. The comparison of the four-class separation by position shows a great degradation of the percent of the site correct. The results are shown below:

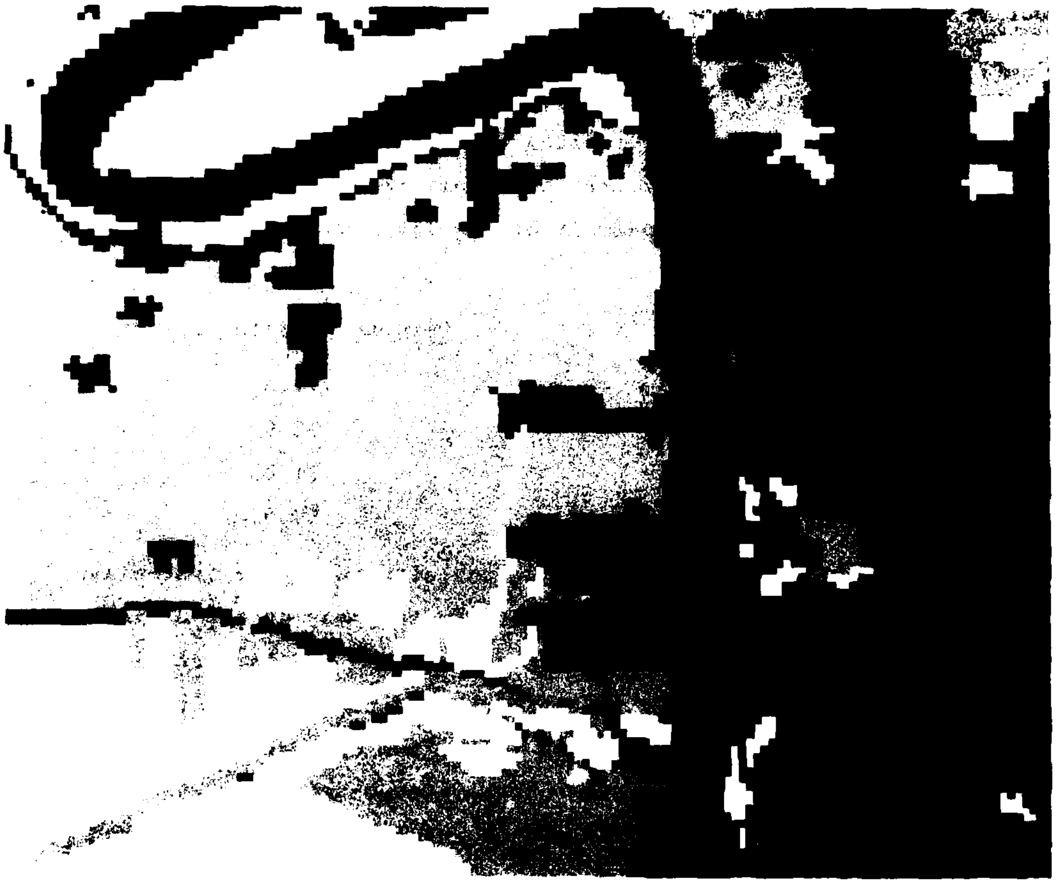
	Percent of Site Correct
Port Allen 1972, 100 m	74.3
Port Allen 1972, 50 m	73.6
Baton Rouge 1972	71.6
Baton Rouge 1977	59.5

78. Another factor in the poor correlation of the four-class separation using the new comparison by position may be the difference in the gridding procedures for photo interpretation and Landsat classification. The Landsat array was rectified to UTM coordinates from an existing array by locating common points in the two data sets and computing the rectification constants. The photo-interpreted array was constructed from digitized patch data with a set of rules governing the border pixel selection. It was brought into accordance with UTM coordinates manually from a topographic map.

Other Evaluations

Size and shape of pixel and patches

79. Reducing the size of the grid (paragraph 65) seems to have very little effect on the accuracy. The three classes by area comparison show a slight improvement as shown in Tables 12 and 18. However, the



a. Photography - October 1974

Figure 33. Water (black), woods (white), open space (light gray), and urban (dark gray) land-use classes at the Baton Rouge site (Continued)

b. Landsat - February 1977

Figure 33. (Concluded)

area and position comparison shows a loss of accuracy.

80. The size and shape of patches appear to have an influence on the accuracy of classification. In Figure 13, the opportunities for miscalculations occur along the interface of the "other" class with water and woods. The number of pixels along the interface is small compared to the total "other" class, which means a small percent of misclassifications. Patches with many irregularities along the border resulting in a large number of pixels along the interface compared to the number within the border of the patch have more opportunity for misclassification. This may account for the lower accuracy of the 50-m pixel classification of Port Allen for the four-class separation. Compare the photo interpretations in Figures 11 and 12.

81. The effect of shape can be seen in Figure 12. In Figure 12a, the photo interpretation shows three one-pixel-wide roads (darkest shade): one in the north-south direction on the upper west side of the scene, another in the east-west direction in the southern part of the scene, and the third nearby in a slightly southeast to northwest direction. The Landsat scanner will cross this scene at 9.76 deg east of north (Table 2). Figure 12b shows that the long narrow shape of the first road with orientation across the scan has almost disappeared as has the second road. A good portion of the third road has been identified. This road is closer to paralleling the scan line and, even though it is only one pixel wide, it was picked up and classified as the road patch. In Figure 12c, the north-south road is two pixels wide and the Landsat interpretation retains the road in Figure 12d.

Detection of changes

82. An evaluation was made of the ability of Landsat to detect change. Two good examples are shown between the 1972 and 1977 Baton Rouge sites. In the upper right corner of the site in Figure 2, the new interstate highway leading out of Baton Rouge to the northeast can be seen to come to an abrupt end at a wooded patch where the construction ended. The Landsat classification shows the wooded patch although only part of the highway is shown (Figure 14). The 1974 aerial photography (Figure 15) shows the road under construction moving into the wooded

patch, and the 1977 Landsat shows the road completed through the west side of the wooded patch in Figure 33 and more clearly in the color pictures, Figures 22 and 23.

83. Another example of change detection is in the Port Allen site. In the 1972 photographs, north of Highway 10 and west of Highway 1, new subdivisions with few trees and bare ground give a high reflectance, as can be seen in Figures 2, 7, and 12. It is speculated that by 1977 these subdivisions had older trees and lawns, causing the reflectance values to be lower and to be classed as open space. In Figure 33, this area retains the high reflectance of major streets, but has lost the high reflectance it had when the subdivision was new. Again Figures 22 and 23 show the change from Figures 2 and 12.

Limited number of classes

84. A look at the class ranges of each site revealed that both February and October Satartia scenes had class ranges for woods and other classes slightly higher than the Baton Rouge scenes. Table 20 lists all class ranges used in this study. The decision to limit the number of classes to three and four and to force the inclusiveness of all pixels in the site results in a loss of information about where misclassification is most likely to occur. Perhaps a better understanding could be obtained (concerning the mixture of reflectance values as one class gradually becomes dominant in a land space) by leaving the ranges unstretched and studying the signatures of these unclassified pixels, rather than making all pixels inclusive. Or, perhaps relationships between bands in the mixed reflectances could be established.

Photo interpretation limitations

85. Some limitations of photo interpretation were discovered. The quality of available aerial photography is vital to the reliability of the standard map. Manual input required at several stages of developing a photo-interpreted standard can be the source of errors. Two of these manual inputs are the land-use interpretation and the digitizing effort to place the data on magnetic tapes for use in the computer.

86. A cursory evaluation was made of the classification of a site in the Atchafalaya Basin that was on the Landsat scenes used in this

study. The area is shown in Figure 26, which is a reduction of the quadrangle containing the site. The site includes large swampy areas containing woods and water. A photo interpretation was made as shown in Figure 28. The interpreter was unable to show all the small patches of water and approximated total areas in several medium size patches. Landsat classification, shown in Figure 27, was able to distinguish water not visible to the interpreter in the photography. This could have been caused either by accumulation of water in the low-lying, flat areas between the time of the photograph and the Landsat overpass, or by the lack of experience of the person doing the photo interpretation. The Landsat classification gave a more accurate picture of the area in digital data that can be summed for more accurate acreage determination.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

87. The classification procedure described by Struve, Grabau, and West (1977b)* and developed with data from the Satartia site works equally as well for the Baton Rouge site and the Satartia site to identify water, woods, and other (nonwater, nonwoods) land use (paragraphs 71-73 and Tables 12 and 18). The unguided procedure introduced in this study classified water, woods, and other land use within 5.1 percent of the Satartia classification and within 3.1 percent of the guided procedure for the same data (Table 18). This indicates that the unguided procedure is adequate for most uses of these three land-use classes.

88. No satisfactory separation of inclusive urban land use was obtained from the guided procedure. The results do suggest a method of locating possible urban areas (i.e., the red areas in Figures 22 and 23 identify surfaces giving the highest reflectance values in band 4). These are surfaces such as concrete, sand, bare earth, rock, rooftops, and metal, surfaces most often found in urban areas and in highways connecting urban centers. Though they do not outline the urban area, there are aggregates of these pixels that suggest the locations of urban centers. The results do indicate that industrial areas and large business areas can be identified very well (Figures 12, 14, and 33).

89. One of the problems to be overcome in identifying a total urban area is the integration of reflectance from concrete, rooftops, and trees that make up residential areas of the cities (paragraph 76).

90. This study again attests to the capability of Landsat data to detect change. At least two significant changes in land use from 1972 to 1977 were detected: the change in an interstate highway through a wooded patch and the change in a new residential area over a 5-year period; i.e., the growth of trees, lawns, and other vegetation dilutes, to some

---

* Ibid.

degree, the high reflectance from rooftops, streets, and driveways (paragraphs 82 and 83).

91. It is evident that percent area of the site is not a complete evaluation of the success of the classification. The position of the pixel must also be accurate for correct classification (Tables 18-19).

92. The new automated program for evaluating the classification (for area and position) produced results for area, as percent of site, very close to those produced by using the overlay procedure (Tables 12 and 18).

93. There are limitations in the use of aerial photography as standards for comparison in the success of the Landsat classification. Some of these are the availability of good quality photography, the errors introduced in manual interpretation and digitizing of the land-use patches, and the gridding procedure that may introduce differences of a pixel width in patch boundaries. This has not been researched, but should be investigated.

94. There are also limitations in the Landsat data that affect correct classification. Three important ones are shape, size, and orientation. The shape of a land-use patch with very long borders compared to the total patch area such as long, narrow patches increases the opportunity for misclassifications when the scan pixel falls across the border and not completely within or outside the patch. In the large patch with the misclassification opportunities along borders (which have an area relatively small compared to the total patch area), a much higher percent of successful classifications is possible. The larger the patch, the better opportunity for good classifications (paragraphs 80 and 81).

95. In summary, the results of this study show that the guided procedure developed by WES can be used in sites other than Satartia (the development site) to identify water, forested, and other land use. Heavy industrial and commercial areas can be identified, but the extent of urban areas including residential parks and open spaces cannot be identified with the present system. Changes in land use are successfully detected by the classification system. An unguided procedure was demonstrated that proved to be adequate for the three land-use

classifications in this study. Finally, automated procedures have been developed to extract portions of a Landsat scene, rectify it to UTM coordinates, and fit it to a gridded map derived from aerial photography. An automated comparison program calculates the total area of the maps, the class areas in the maps, and the percent of area correctly classified in each land-use patch and in the map as a whole. The standard maps in this study were from aerial photography. The user may select any map of his choice as a standard for use in the automated comparison program.

Recommendations

96. Based on the findings of this study, the following recommendations are considered warranted:

- a. The effect of shape, size, and orientation of land-use patches on Landsat data should be studied to determine the degree of accuracy that can be expected from Landsat land-use classification when small, narrow, or disoriented patches exist.
- b. The WES classification system should be tested in sites unlike Satartia and Baton Rouge.
- c. The study of reflectance from urban areas should be continued, perhaps investigating variance, a definition of texture, pattern recognition, and/or a mathematical relationship between reflectance bands of samples from the urban data.

Table 1

Characteristics of Landsat Data Sets for Two Scenes Including Baton Rouge, Louisiana

Landsat Scene No.	Coordinates of Center of Scene		Date of Satellite Overpass	Time of Overpass (Local Time)			Cloud Cover %	Sun Azimuth deg N	Sun Elevation deg From Zenith
	Latitude	Longitude		Hr	Min	Sec			
1070-16073	30°22'N	90°53'W	1 Oct 72	10	7	30	0	138	47
2768-15410	30°15'N	91°08'W	28 Feb 77	9	41	0	0	129	36

Table 2

Data Used to Bring Landsat and Aerial Photography into Geometric Accordance

Landsat Scene	Day of Overpass	Area of Interest	Aerial Photograph	θ_f	$D_X(D_Y)$
1070-16073	1 October 1972	Port Allen	February 1972	9.76°	58.5 m
2768-15410	28 February 1977	Baton Rouge	February 1974	12.17°	58.1 m

Table 3

Data Used to Rectify Landsat with UTM Coordinates of a Topographic Map

Landsat Scene	Day of Overpass	Area of Interest	Topographic Map	θ_f	D_X	D_Y
1070-16073	1 October 1972	Baton Rouge and Port Allen	1:250,000	9.61°	57.40 m	78.53 m
2768-15140	28 February 1977	Baton Rouge and Port Allen	1:250,000	9.39°	58.05 m	78.94 m
2768-15140	28 February 1977	*Atchafalaya*	1:250,000	9.26°	57.64 m	79.39 m

AD-A092 807 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 8/6
ACQUISITION OF TERRAIN INFORMATION USING LANDSAT MULTISPECTRAL --ETC(U)
SEP 80 M H SMITH, H STRUVE
UNCLASSIFIED WES-TR-M-77-2-3 NL

2 OF 2
AD
A092807

END
DATE
FILMED
1 81
DTIC

Table 4

Mean and Standard Deviation of Sample Data Arrays

Port Allen Site - 1 October 1972 Landsat

Terrain Type	Sample Number	Band No. - Mean (Standard Deviation), CCT Units			
		Band 4	Band 5	Band 6	Band 7
Wooded	1	21.67(1.22)	12.33(0.71)	33.22(1.09)	21.44(0.73)
	2	21.11(1.05)	12.44(0.53)	32.56(1.42)	21.22(0.67)
	3	20.22(0.44)	11.89(0.78)	33.89(1.05)	22.44(0.53)
Water	4	30.00(0.00)	27.44(0.73)	20.33(0.50)	3.89(0.33)
	5	28.22(1.09)	27.00(0.71)	20.33(1.22)	3.89(0.60)
	6	29.11(0.93)	26.78(1.30)	20.11(1.45)	3.89(0.78)
Urban (New residential)	7	31.56(0.73)	24.67(1.50)	43.56(1.59)	24.56(1.42)
	8	32.00(1.94)	25.78(1.79)	41.67(1.12)	23.11(0.78)
	9	31.78(2.86)	25.22(2.05)	42.11(2.42)	23.11(1.27)
Urban (Older residential)	10	29.33(0.87)	21.89(1.45)	40.33(2.00)	22.89(1.69)
	11	30.22(2.11)	22.33(2.40)	42.44(1.81)	24.11(0.33)
	12	25.89(1.27)	18.00(2.50)	36.00(4.03)	22.78(1.72)
Urban (Industrial)	13	36.00(5.27)	30.22(6.96)	49.44(4.88)	26.67(2.83)
	14	35.89(4.62)	31.44(5.92)	48.00(2.55)	26.78(3.42)
	15	35.11(3.37)	30.89(4.48)	47.33(3.28)	26.11(1.62)
Open space	16	27.00(0.00)	18.14(1.24)	47.89(1.27)	28.33(0.87)
	17	30.44(1.51)	26.33(1.12)	33.22(3.60)	17.33(2.12)
	18	28.89(1.36)	22.11(0.93)	47.00(2.12)	29.44(1.24)
	19	31.56(3.43)	26.67(5.43)	35.76(5.65)	18.78(5.02)
	20	30.67(1.58)	24.67(1.00)	41.44(3.09)	22.67(1.94)
	21	30.56(1.51)	24.44(2.60)	40.11(2.57)	21.67(2.40)

Table 5

Land-Use Class Ranges for 1.75 Variance Windows, Port Allen Site

Terrain Type	Sample Number	Band No. - Land-Use Class Range, CCT Units			
		Band 4	Band 5	Band 6	Band 7
Woods	1	20–23	11–14	31–35	20–23
	2	19–23	11–14	31–34	19–31
	3	18–22	10–14	32–36	21–24
	1–3	18–23	10–14	31–36	19–31
Water	4	28–32	26–29	19–22	2–6
	5	26–30	25–29	19–22	2–6
	6	27–31	25–29	18–22	2–6
	4–6	26–32	25–29	18–22	2–6
Urban (Residential)	7	30–33	23–26	42–45	23–26
	8	30–34	24–28	40–43	21–25
	9	30–34	23–27	40–44	21–25
	10	28–31	20–24	39–42	21–25
	11	28–32	21–24	41–44	22–26
	12	24–28	16–20	34–38	21–25
	7–12	24–34	16–28	34–45	21–26
Urban (Industrial)	13	34–38	28–32	48–51	25–28
	14	34–38	30–33	46–50	25–29
	15	33–37	29–33	46–49	24–29
	13–15	33–38	28–33	46–51	24–29
Open space	16	25–29	16–20	46–50	27–30
	17	29–32	25–28	31–35	15–19
	18	29–32	25–28	31–35	15–19
	19	30–33	25–28	34–38	17–21
	16–19	25–33	16–28	31–50	15–31

Table 6

Mean and Standard Deviation of Site Data Arrays

Baton Rouge Site, 28 February 1977 Landsat

Terrain Type	Sample Number	Band No. - Mean (Standard Deviation), CCT Units			
		Band 4	Band 5	Band 6	Band 7
Wooded	1	12.67 (0.87)	13.78 (0.67)	19.44 (1.33)	10.22 (0.44)
	2	13.22 (0.67)	14.11 (0.78)	23.00 (0.71)	12.11 (0.33)
	3	12.78 (0.67)	14.22 (0.83)	19.67 (0.87)	9.89 (1.05)
	4	13.33 (0.87)	14.11 (0.33)	20.11 (1.05)	10.67 (0.71)
Urban (Residential)	5	18.33 (1.00)	21.78 (1.92)	29.33 (2.12)	13.56 (0.88)
Urban (Stadium)	6	27.44 (6.31)	31.89 (7.77)	41.89 (3.41)	17.78 (1.39)
Urban (Business)	7	27.56 (1.33)	34.89 (2.37)	35.00 (2.24)	13.11 (0.93)
Urban (Downtown)	8	16.89 (1.45)	19.78 (2.33)	25.89 (3.06)	11.56 (1.01)
Urban (Cemetery)	9	20.78 (1.79)	27.22 (2.22)	39.44 (3.91)	20.00 (1.87)
Urban (Woods)	10	13.67 (1.22)	15.00 (1.00)	23.67 (2.50)	12.44 (1.01)
Urban (Residential)	11	14.22 (1.09)	16.00 (0.87)	28.00 (3.00)	14.67 (1.22)
	12	16.11 (0.33)	18.56 (1.13)	28.00 (1.00)	13.22 (0.44)

(Continued)

Table 6 (Continued)

Terrain Type	Sample Number	Band No. - Mean (Standard Deviation), CCT Units			
		Band 4	Band 5	Band 6	Band 7
Urban	13				
(Industrial)		30.33 (1.87)	40.22 (3.27)	42.76 (3.56)	15.56 (1.74)
Urban	14				
(Large roofs and parking)		31.89 (5.33)	41.11 (5.86)	44.44 (3.47)	18.22 (0.83)
Open	15				
(Fields)		18.67 (1.50)	23.89 (1.90)	37.11 (2.32)	18.78 (1.78)
	16	20.11 (0.78)	25.44 (1.24)	29.56 (2.35)	12.56 (0.73)
	17	18.33 (1.00)	24.33 (1.00)	28.00 (1.80)	11.67 (0.71)
	18	19.11 (1.05)	24.44 (1.01)	28.33 (1.12)	11.22 (0.67)
	19	19.44 (0.73)	24.67 (1.32)	26.78 (1.86)	11.11 (0.60)
	20	18.56 (1.13)	19.33 (0.50)	38.11 (3.14)	17.44 (1.67)
Village	21	19.56 (2.01)	24.67 (3.39)	32.00 (1.87)	14.11 (1.05)
Water	22				
(Miss. River)		17.11 (0.33)	20.78 (0.67)	14.00 (1.12)	1.11 (0.33)
	23	17.44 (0.53)	20.67 (0.50)	13.33 (0.87)	1.44 (0.73)
Water	24				
(Lake)	Original	13.00 (0.71)	12.11 (0.60)	8.89 (2.32)	1.11 (1.62)
	Revised	12.88 (0.64)	12.00 (0.53)	8.13 (0.35)	0.63 (0.74)
Water	25				
(Miss. River)		17.33 (0.71)	19.78 (0.67)	12.44 (1.01)	1.11 (0.60)
Water	26				
(Intracoastal Waterway)	Original	15.22 (1.79)	19.22 (3.53)	19.44 (2.70)	6.56 (2.88)

(Continued)

(Sheet 2 of 3)

Table 6 (Concluded)

Terrain Type	Sample Number	Band No. - Mean (Standard Deviation), CCT Units			
		Band 4	Band 5	Band 6	Band 7
	Revised	16.60 (0.89)	22.00 (1.58)	17.60 (1.67)	4.20 (0.84)
Water (Miss. River)	27	17.89 (0.93)	20.44 (0.73)	13.33 (1.41)	1.33 (0.50)

(Sheet 3 of 3)

Table 7

Reflectance Ranges for Variance Windows of 1.75 and 2.25

for Woods and Water Samples, Baton Rouge Site

Variance Window	Terrain Type	Sample Number	Band No. - Reflectance Ranges, CCT Units			
			Band 4	Band 5	Band 6	Band 7
1.75	Woods	1	11-14	12-16	18-21	8-12
		2	11-15	12-16	21-25	10-14
		3	11-15	12-16	18-21	8-12
		4	12-15	12-16	18-22	9-12
		1-4	11-15	12-16	18-25	8-14
	Water	22	15-19	19-23	12-16	0-3
		23	16-19	19-22	12-15	0-3
		24	11-15	10-14	6-10	0-2
		25	16-19	18-22	11-14	0-3
		26	15-18	20-24	16-19	2-6
		27	16-20	19-22	12-15	0-3
		22-27	11-20	10-24	6-19	0-6
2.25	Woods	1	10-15	12-16	17-22	8-12
		2	11-15	12-16	21-25	10-14
		3	11-15	12-16	17-22	8-12
		4	11-16	12-16	18-22	8-13
		1-4	10-16	12-16	17-25	8-14
	Water	22	15-19	19-23	12-16	0-3
		23	15-20	18-23	11-16	0-4
		24	11-15	10-14	6-10	0-3
		25	15-20	18-22	10-15	0-3
		26	14-19	20-24	15-20	2-6
		27	16-20	18-23	11-16	0-4
		22-27	11-20	10-24	6-20	0-6

Table 8

Reflectance Values From an Array of Pixels in Baton Rouge

Band	Reflectance Values, CCT Units						
7	14	15	14	14	12	13	14
	14	15	16	15	15	16	13
	17	17	19	20	17	17	12
	20	17	15	15	15	17	13
	19	17	13	12	14	13	12
	13	13	13	14	22	24	17
	19	14	14	18	21	18	18
6	41	41	36	36	31	36	39
	39	42	36	36	32	42	36
	44	39	48	48	39	41	33
	50	41	39	41	39	41	37
	43	40	35	32	38	37	32
	34	43	38	34	52	61	47
	43	33	35	41	51	45	43
5	42	43	37	34	30	34	37
	38	41	35	31	35	43	38
	39	39	41	39	33	35	33
	45	33	33	38	36	38	36
	43	35	33	35	37	35	33
	31	33	36	33	42	47	42
	37	27	31	34	42	42	37
4	30	32	28	28	24	27	28
	31	33	29	24	26	33	29
	31	30	31	31	27	30	26
	36	29	28	29	29	29	28
	33	31	29	29	29	29	26
	26	26	29	26	33	41	30
	28	23	23	27	32	32	30

Table 9

Class Ranges From Samples With 1.75 Variance

Terrain Type	Sample Number	Band No. - Class Ranges, CCT Units			
		Band 4	Band 5	Band 6	Band 7
Woods	1	11-14	12-16	18-21	8-12
	2	11-15	12-16	21-25	10-14
	3	11-15	12-16	18-21	8-12
	4	12-15	12-16	18-22	9-12
	1-4	11-15	12-16	18-25	8-14
Urban	6*	26-29	30-34	40-44	16-20
	7*	26-29	33-37	33-37	11-15
	8	15-19	18-22	24-28	10-13
	11	12-16	14-18	26-30	13-16
	12	14-18	17-20	26-30	11-15
	13*	29-32	38-42	41-45	14-17
	14*	30-34	39-43	43-46	16-20
	8,11,12	12-34	14-43	24-46	10-20
	6,7,13,14	26-34	30-43	33-46	11-20
Open space	16	18-22	24-27	28-31	11-14
	17	17-20	23-26	26-30	10-13
	18	17-21	23-26	27-30	9-13
	19	18-21	23-26	25-29	9-13
	20	17-20	18-21	36-40	16-19
	21	18-21	23-26	30-34	12-16
	16,-21	17-21	18-26	25-40	9-19
Water	22	15-19	19-23	12-16	0-3
	23	16-19	19-22	12-15	0-3
	24	11-15	10-14	6-10	0-2
	25	16-19	18-22	11-14	0-3
	26	15-18	20-24	16-19	2-6
	27	16-20	19-22	12-15	0-3
	22-27	11-20	10-24	6-19	0-6

* High reflectance in band 4.

Table 10

Signatures of Means by Reflectance Similarity in Bands, Baton Rouge Site, 28 February 1977 (Partial Listing)

Count	Band No. - Reflectance Value, CCT Units			
	Band 4	Band 5	Band 6	Band 7
1	13	9	4	0
1	12	11	9	0
1	13	11	9	0
1	13	12	9	0
2	13	11	8	1
1	13	12	8	1
3	13	11	9	1
1	13	11	10	1
10	17	20	12	1
23	18	20	12	1
7	18	21	12	1
9	19	21	12	1
50	17	20	13	1
50	18	20	13	1
5	19	20	13	1
24	17	21	13	1
82	18	21	13	1
15	19	21	13	1
7	18	22	13	1
2	19	22	13	1
1	16	20	14	1
22	17	20	14	1
15	18	20	14	1
1	19	20	14	1
32	17	21	14	1
82	18	21	14	1
13	19	21	14	1
11	18	22	14	1
3	19	22	14	1
1	18	21	15	1
1	11	10	8	2
8	17	20	13	2
4	18	20	13	2
6	17	21	13	2
10	18	21	13	2

Table 11

Frequency of Occurrence of Means Signatures, Baton Rouge Area, Landsat 2768-15410, 28 February 1977 (Partial Listing)

Count	Band No. - Reflectance Values, CCT Units			
	Band 4	Band 5	Band 6	Band 7
290	13	15	21	11
243	13	15	22	11
174	13	14	21	11
165	13	14	20	10
147	14	15	21	11
121	13	14	22	11
110	13	15	23	11
82	18	21	14	1
82	18	21	13	1
77	14	15	22	11
70	13	15	20	11
68	13	14	21	10
63	13	15	20	10
63	13	14	19	10
60	13	15	21	10
58	13	14	20	11
55	13	15	23	12
50	18	20	13	1
50	17	20	13	1
45	13	15	22	12
42	14	15	22	12
37	18	21	14	2
32	13	15	24	12
32	17	21	14	1
28	13	14	23	11
28	14	16	22	11
25	14	15	23	12
25	13	14	23	12

Table 12

Comparison of Land-Use Classification With Photo Interpretation

(By Class Acreage and Percent to Total of Site)

	Photo Interpretation				Landsat				Difference, % (Landsat Less Air Photo)	
	Three Classes		Other Classes		Three Classes		Other Classes			
	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Three Classes	Other Classes
Satartia - Report 2* Development Site										
Total site	38,054.2	100.0			38,054.2	100.0			--	
Water	608.9	1.6			494.7	1.3			-0.3	
Forest (woods)	19,065.1	50.1			19,940.4	52.4			+2.3	
Other	18,380.2	48.3			17,619.1	46.3			-2.0	
Urban			--	--			--	--		--
Open space			--	--			--	--		--
Port Allen - 1972 - 100-m Grid										
Total site	8,989.8	100.0			8,989.8	100.0			--	
Water	430.0	4.8			499.2	5.6			+0.8	
Woods (forest)	939.0	10.4			696.8	7.8			-2.6	
Other	7,620.8	84.8			7,793.7	86.6			+1.8	
Urban			1,640.8	18.3			1,289.9	14.3		-4.0
Open space			5,980.0	66.5			6,503.8	72.3		+5.8
Port Allen - 1972 - 50-m Grid										
Total site	8,956.3	100.0			8,956.3	100.0			--	
Water	421.9	4.7			501.0	5.6			+0.9	
Woods (forest)	866.1	9.7			718.5	8.0			-1.7	
Other	7,668.3	85.6			7,736.8	86.4			+0.8	
Urban			1,610.5	18.0			1,318.9	14.7		-3.3
Open space			6,059.0	67.6			6,416.7	71.7		+4.1

(Continued)

* Ibid.

Table 12 (Concluded)

	Photo Interpretation				Landsat				Difference, % (Landsat Less Air Photo)	
	Three Classes		Other Classes		Three Classes		Other Classes			
	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Three Classes	Other Classes
Baton Rouge - 1972 - 100-m Grid										
Total site	43,396.6	100.0			43,396.6	100.0			--	
Water	4,979.2	11.5			4,924.8	11.4			-0.1	
Woods (forest)	7,919.7	18.3			7,439.2	17.4			-0.9	
Other	30,497.7	70.3			30,932.6	71.3			+1.0	
Urban			14,865.8	34.3			8,834.0	20.4		-13.9
Open space			15,631.9	36.0			22,098.6	50.9		+14.9
Baton Rouge - 1977 - 100-m Grid - Guided										
Total site	42,446.5	100.0			42,446.5	100.0			--	
Water	6,029.4	14.2			5,048.4	11.9			-2.3	
Woods (forest)	8,475.7	20.0			7,628.1	18.0			-2.0	
Other	27,941.4	65.8			29,770.0	70.1			+4.3	
Urban			14,650.9	34.5			5,082.9	12.0		-22.5
Open space			13,290.5	31.3			24,687.1	58.1		+26.8
Baton Rouge - 1977 - 100-m Grid - Unguided										
Total site	42,446.5	100.0			42,446.5	100.0			--	
Water	6,029.4	14.2			5,048.4	11.9			-2.3	
Woods (forest)	8,475.7	20.0			6,313.5	14.9			-5.1	
Other	27,941.4	65.8			31,084.6	73.2			+7.4	
Urban			14,650.9	34.5			8,364.5	19.7		-14.8
Open space			13,290.5	31.3			22,720.1	53.5		+22.2

Table 13

Control Point Locations for Landsat and Aerial Photography

(Baton Rouge Map Arrays, 1977 Data)

	Control Point Locations			
	Standard		Other	
No.	X	Y	X	Y
1	6.30	8.20	12.00	11.00
2	14.00	27.00	21.00	29.00
3	84.00	20.00	90.00	18.00
4	74.00	63.00	82.00	61.00
5	9.60	102.20	18.00	107.00
6	25.40	122.00	36.00	125.00
7	40.70	81.10	50.00	82.00
8	90.00	87.00	99.00	85.00
9	132.80	17.70	137.00	12.00
10	120.70	57.80	127.00	53.00
11	104.00	64.20	110.00	62.00
12	101.20	95.20	108.00	92.00
13	144.80	66.50	151.00	61.00
14	125.00	118.30	134.00	114.00
15	110.00	124.60	119.00	121.00

Table 14

Differences Between Projected and Actual Distances of the Control Points (Grids) in Table 13

Other Control Points	Standard Control Points														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	*	-0.25	-0.99	-0.54	-4.26	-3.70	-1.65	-1.45	-0.18	0.14	0.15	0.69	0.	-0.85	-0.63
2	*	*	-0.65	-0.15	-4.43	-3.64	-1.37	-0.98	0.01	0.54	0.81	1.24	0.49	-0.36	-0.17
3	*	*	*	-0.57	-5.78	-4.69	-2.11	-1.85	0.69	0.73	-0.86	-0.73	0.50	-1.40	-1.62
4	*	*	*	*	-4.76	-3.90	-1.04	-1.16	-0.80	0.53	1.53	0.85	0.75	-0.49	-0.64
5	*	*	*	*	*	-0.63	-3.70	-3.44	-5.58	-4.02	-2.37	-0.85	-3.19	-1.57	-0.77
6	*	*	*	*	*	*	-2.51	-2.44	-4.72	-3.21	-1.41	-0.15	-2.20	-0.54	0.19
7	*	*	*	*	*	*	*	-0.24	-1.88	-0.33	1.20	2.25	0.27	0.68	1.10
8	*	*	*	*	*	*	*	*	-2.54	-0.96	0.70	2.23	0.25	0.61	0.51
9	*	*	*	*	*	*	*	*	*	-1.24	-3.26	-3.21	-1.82	-3.42	-3.61
10	*	*	*	*	*	*	*	*	*	*	-1.65	-2.10	-0.11	-2.12	-2.34
11	*	*	*	*	*	*	*	*	*	*	*	0.36	-0.80	-0.50	-0.35
12	*	*	*	*	*	*	*	*	*	*	*	*	-1.75	-1.53	-1.00
13	*	*	*	*	*	*	*	*	*	*	*	*	*	-1.41	-1.69
14	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-0.56
15	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 15

Correctly Identified Land-Use Grid Spaces for Baton Rouge

1977 Landsat Classification*

Patch Value, Other Map	Number of Occurrences: Patch Value, Standard Map 1	2	3	4	TOTAL	
1	1751	116	48	20	1,935	Water
2	94	1862	470	148	2,574	Woods
3	404	852	4300	4143	9,699	Open space
4	58	71	166	1811	2,106	Urban
Total	2307	2901	4984	6122	16,314	

Water: Class 1

Woods: Class 2

Open space: Class 3

Urban: Class 4

* See paragraph 64 in the text.

Table 16

Distribution of Classes on Other Map by Patch Number (Partial Listing)

Standard Map Patch			Grids on Other Map Overlaying Patches on Standard Map				
			Correct	Number of Grids by Class			
Number	Class	Grids	Class	1	3	4	5
1	5	5849	5	48	66	2887	2848
2	1	1696	1	1578	16	78	24
5	3	642	3	31	583	28	0
6	1	2	1	0	2	0	0
7	4	5	4	0	2	3	0
8	4	3	4	0	3	0	0
9	3	3	3	0	3	0	0
11	3	3	3	0	0	3	0
12	3	61	3	4	41	16	0
13	1	2	1	0	1	1	0
14	4	4445	4	38	58	4029	320
15	5	6	5	0	0	4	2
16	5	4	5	0	0	4	0
17	5	2	5	0	0	2	0
18	5	14	5	0	0	13	1

Table 17

Summary Table of Class Correlation by Patch and Map Area

Standard Map Patch				Correlation of Other With Standard Map					
		Area		Correct			Incorrect		
Number	Class	Grids	Square Kilometres	Grids	% Patch	% Map	Grids	% Patch	% Map
13	1	1559	15.59	947	60.7	5.1	612	39.3	3.3
4	1	631	6.31	460	72.9	2.5	171	27.1	0.9
157	1	79	0.79	61	77.2	0.3	18	22.8	0.1
22	1	65	0.65	29	44.6	0.2	36	55.4	0.2
115	1	43	0.43	11	25.6	0.1	32	74.4	0.2
69	1	22	0.22	0	0.	0.	22	100.0	0.1
84	1	20	0.20	0	0.	0.	20	100.0	0.1
68	1	18	0.18	0	0.	0.	18	100.0	0.1
57	1	16	0.16	0	0.	0.	16	100.0	0.1
81	1	11	0.11	1	9.1	0.0	10	90.9	0.1
39	1	6	0.06	0	0.	0.	6	100.0	0.0
156	1	3	0.03	0	0.	0.	3	100.0	0.0
140	1	2	0.02	0	0.	0.	2	100.0	0.0
142	1	2	0.02	0	0.	0.	2	100.0	0.0
143	1	2	0.02	0	0.	0.	2	100.0	0.0

Table 18

Comparison of Land-Use Classification With Photo Interpretation

(By Class Acreage and Percent of Site Using New Comparison Program)

	Photo Interpretation				Landsat				Difference, % (Landsat Less Air Photo)		Percent of Site Correct	
	Three Classes		Other Classes		Three Classes		Other Classes					
	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Three Classes	Other Classes	Three Classes	Four Classes
Port Allen - 1972 - 100-m Grid												
Total site	8,987.2	100.0			8,987.2	100.0			--		98.1	94.7
Water	430.0	4.8			472.0	5.3			+0.5		4.8	4.8
Woods (forest)	936.5	10.4			825.3	9.2			-1.2		9.2	9.2
Other	7,620.7	84.8			7,689.9	85.5			+0.7		84.1	--
Urban			1,640.8	18.3			1,280.0	14.3		-4.1		14.2
Open space			5,979.9	66.5			6,409.9	71.3		+4.8		66.5
Port Allen - 1972 - 50-m Grid												
Total site	8,952.6	100.0			8,952.6	100.0			--		98.2	95.1
Water	421.9	4.7			394.8	4.4			-0.3		4.4	4.4
Woods (forest)	866.1	9.7			733.3	8.2			-1.5		8.2	8.2
Other	7,664.6	85.6			7,824.5	87.4			+1.8		85.6	--
Urban			1,609.9	18.0			1,335.5	14.9		-3.1		14.9
Open space			6,054.7	67.6			6,489.0	72.5		+4.9		67.6
Baton Rouge - 1972 - 100-m Grid												
Total site	43,396.6	100.0			43,396.6	100.0			--		98.8	84.7
Water	4,979.2	11.5			4,949.5	11.4			-0.1		11.4	11.4
Woods (forest)	7,919.7	18.2			7,410.7	17.1			-1.1		17.1	17.1
Other	30,497.7	70.3			31,036.4	71.5			+1.2		70.3	--
Urban			14,865.8	34.3			8,769.8	20.2		-14.1		20.2
Open space			15,631.9	36.0			22,266.6	51.3		+15.3		36.0

(Continued)

Table 18 (Concluded)

	Photo Interpretation				Landsat				Difference, % (Landsat Less Air Photo)		Percent of Site Correct	
	Three Classes		Other Classes		Three Classes		Other Classes					
	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Acreage	Percent of Site	Three Classes	Other Classes	Three Classes	Four Classes
Baton Rouge - 1977 - 100-m Grid												
Total site	45,420.4	100.0			45,420.4	100.0			--		95.1	72.7
Water	6,150.4	13.5			4,882.8	10.7			-2.8		10.7	10.7
Woods (forest)	9,325.7	20.5			8,394.2	18.5			-2.0		18.5	18.5
Other	29,944.3	65.9			32,195.3	70.8			+4.9		65.9	--
Urban			15,807.3	34.9			5,634.0	12.4		-22.5		12.4
Open space			14,136.9	31.1			26,561.3	58.5		+27.4		31.1

Table 19

Comparison of Landsat Classification With Photo Interpretation As Standard

(by Acreage and Position)

	Photo Interpretation (Acreage)		Landsat (Acreage)		Correct Classification			
					Percent of Class		Percent of Site	
	Three Classes	Other Classes	Three Classes	Other Classes	Three Classes	Other Classes	Three Classes	Four Classes
Port Allen - 1972 - 100-m Grid								
Total site	8,987.2		8,238.4		--		91.7	74.3
Water	430.0		378.1		87.9		4.2	4.2
Woods (forest)	936.5		556.0		59.4		6.2	6.2
Other	7,620.7		7,304.3		95.8		81.3	--
Urban		1,640.8		622.7		38.0		6.9
Open space		5,979.9		5,122.5		84.7		57.0
Port Allen - 1972 - 50-m Grid								
Total site	8,952.6		8,224.4		--		91.5	73.6
Water	421.9		332.4		78.8		3.7	3.7
Woods (forest)	866.1		506.6		58.5		5.6	5.6
Other	7,664.6		7,835.4		96.4		82.2	--
Urban		1,609.9		630.1		39.1		7.0
Open space		6,054.7		5,152.8		85.1		57.3

(Continued)

Table 19 (Concluded)

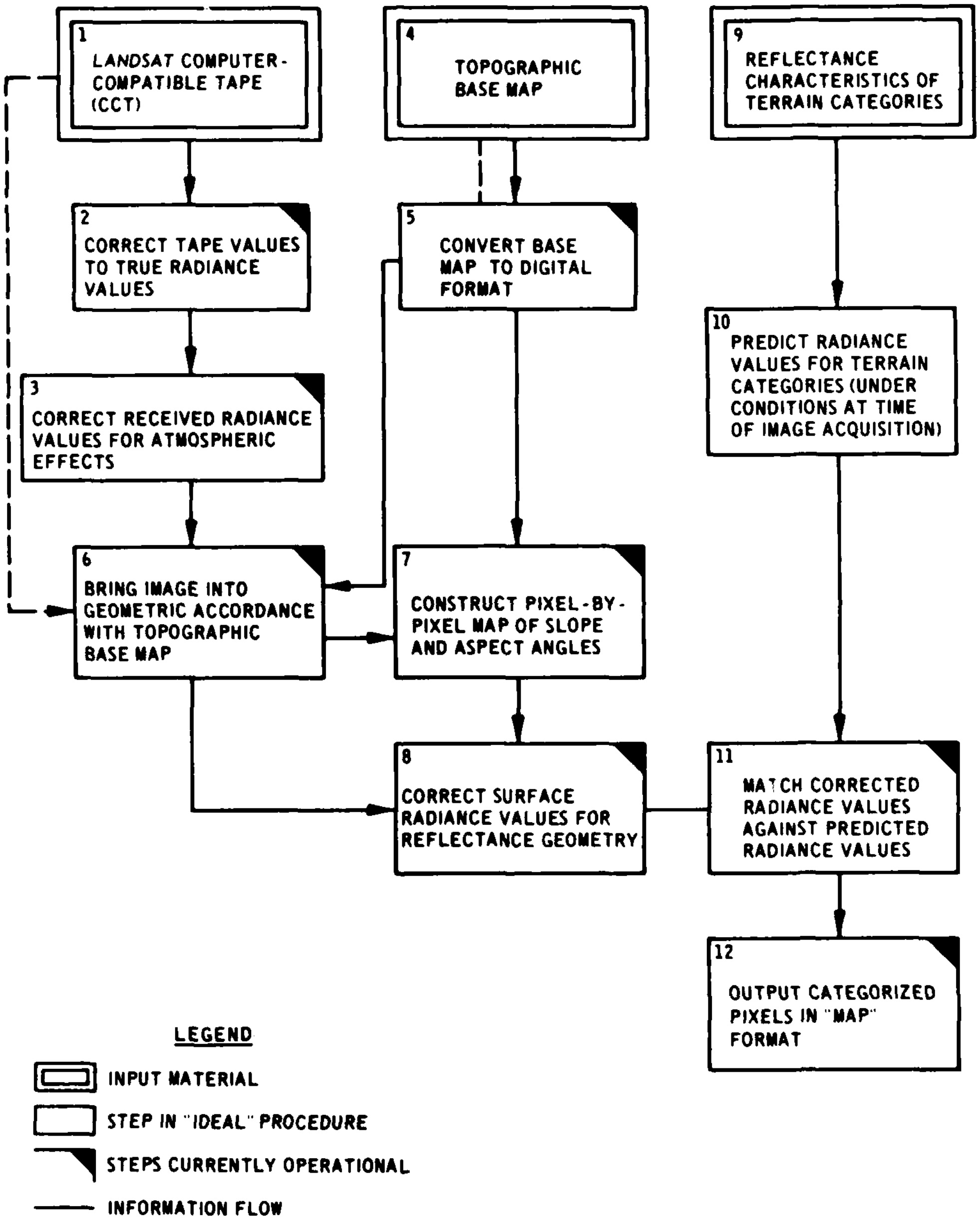
	Photo Interpretation (Acreage)		Landsat (Acreage)		Correct Classification			
					Percent of Class		Percent of Site	
	Three Classes	Other Classes	Three Classes	Other Classes	Three Classes	Other Classes	Three Classes	Four Classes
			Baton Rouge - 1972 - 100-m Grid					
Total site	43,396.6		39,971.7		--		92.1	71.6
Water	4,979.2		4,349.1		87.3		10.0	10.0
Woods (forest)	7,919.7		6,390.1		80.7		14.7	14.7
Other	30,497.7		29,232.5		95.9		67.4	
Urban		14,865.8		7,124.0		47.9		16.4
Open space		15,631.9		13,252.2		84.8		30.5
			Baton Rouge - 1977 - 100-m Grid					
Total site	40,364.6		34,676.4		--		85.9	59.5
Water	5,700.7		4,326.8		75.9		10.7	10.7
Woods (forest)	7,168.5		4,601.1		64.2		11.4	11.4
Other	27,443.5		25,748.4		93.8		63.8	--
Urban		15,127.8		4,475.1		29.6		11.1
Open space		12,315.7		10,625.5		86.3		26.3

Table 20

Class Reflectance Range (CCT Units) by Bands

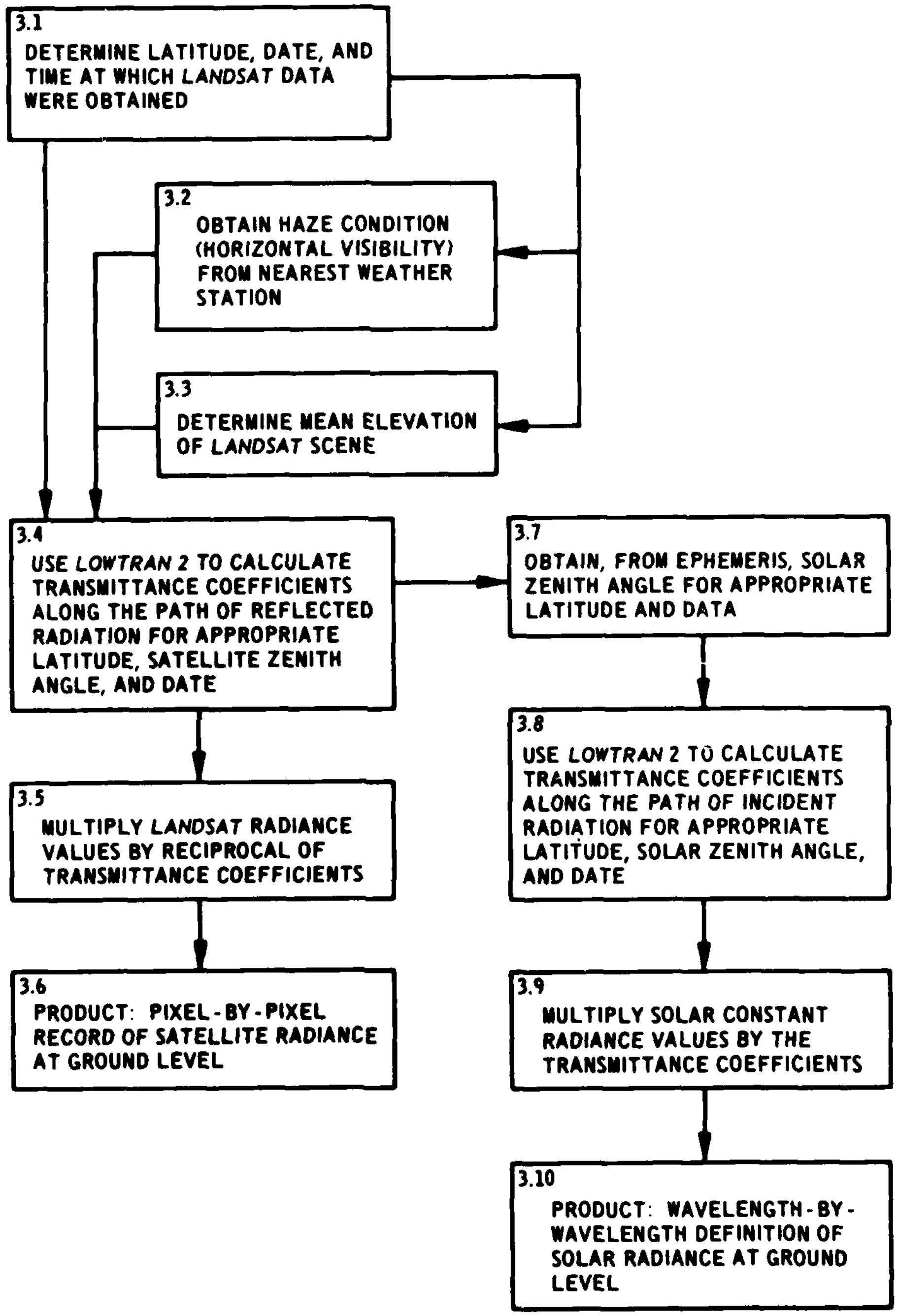
(Landsat 1 Total Range = 0.63; Landsat 2 Total Range = 0.127)

	Procedure Development Site - Report 2				Baton Rouge Site - Guided Classification				Baton Rouge Site - Unguided Classification			
	Band 4	Band 5	Band 6	Band 7	Band 4	Band 5	Band 6	Band 7	Band 4	Band 5	Band 6	Band 7
	October 1975 - Landsat 1				October 1972 - Landsat 1							
Water	0-63	0-63	0-63	0-8	0-63	0-63	0-63	0-12				
Woods (forest)	0-63	0-18	0-63	9-63	0-63	0-14	0-63	13-63				
Other	0-63	19-63	0-63	9-63	0-63	15-63	0-63	13-63				
	February 1975 - Landsat 1				February 1977 - Landsat 2				February 1977 - Landsat 2			
Water	0-63	0-63	0-63	0-8	0-127	0-127	0-127	0-7	0-127	0-127	0-127	0-7
Shallow water	0-63	0-63	0-63	9-19								
Woods (forest)	0-63	0-20	0-63	20-63	0-127	0-16	0-127	8-63	0-127	0-16	0-25	8-63
Other	0-63	21-63	0-63	20-63	0-127	17-127	0-127	8-63	0-127	0-127	26-127	8-63
					October 1972 - Landsat 1							
Water					0-63	0-63	0-63	0-12				
Woods (forest)					0-63	0-14	0-63	13-63				
Urban					33-63	15-63	0-63	13-63				
Open space					0-32	0-63	0-63	13-63				
					February 1977 - Landsat 2							
Water					0-127	0-127	0-127	0-7				
Woods (forest)					0-127	0-16	0-127	8-63				
Urban					23-127	17-127	0-127	8-63				
Open space					0-22	0-127	0-127	8-63				
									February 1977 - Landsat 2			
Water									0-127	0-127	0-127	0-7
Woods (forest)									0-127	0-16	0-25	8-63
Urban									22-127	17-127	0-127	8-63
Open space									0-21	17-127	0-127	8-63
Other (urban)									0-127	0-16	26-127	8-63



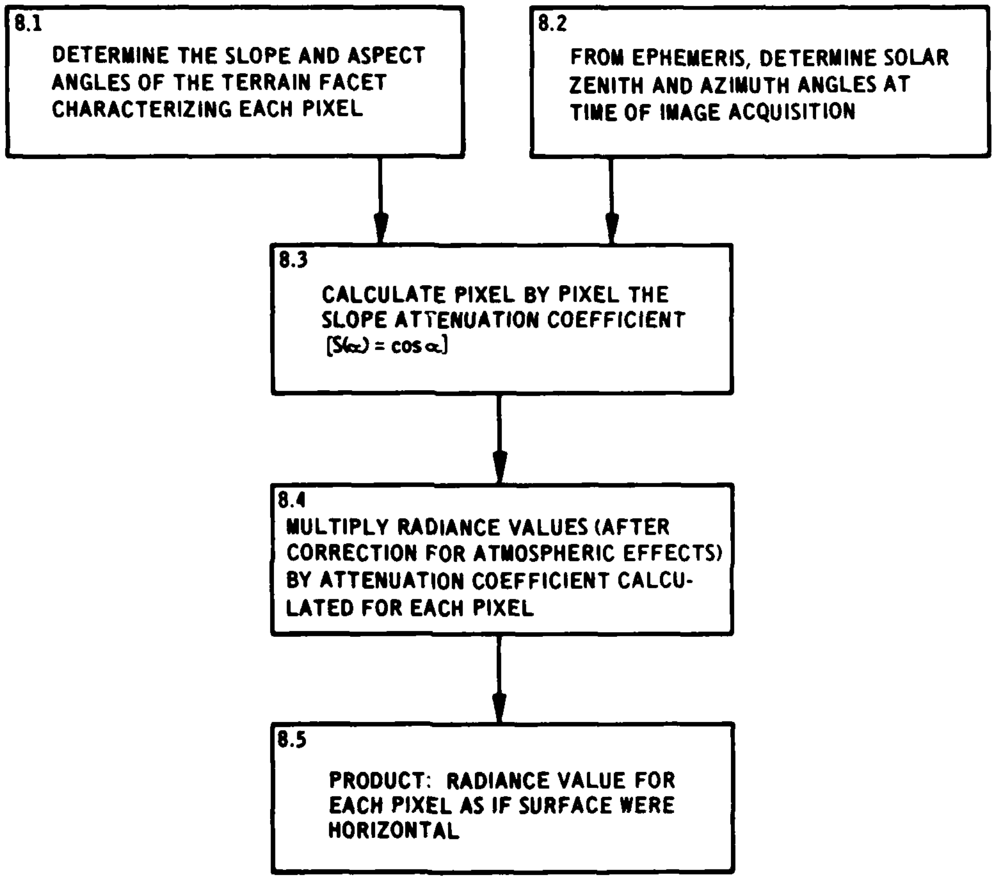
GENERALIZED DIAGRAM OF IDEALIZED PROGRAMMED IMAGE INTERPRETATION SYSTEM

PLATE 1



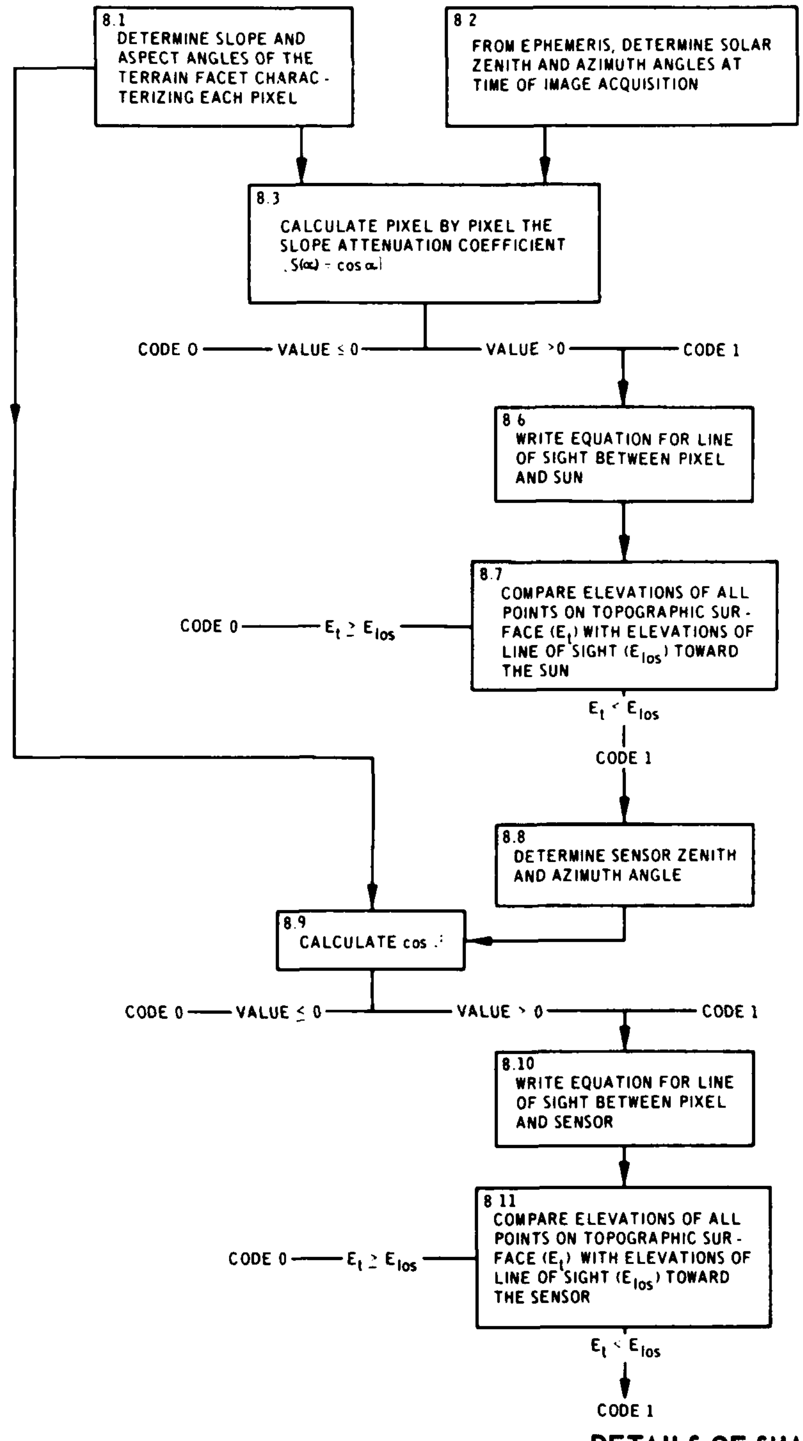
DETAILS OF ATMOSPHERIC CORRECTION PROCEDURE USED IN BLOCK 3, PLATE 1

PLATE 2



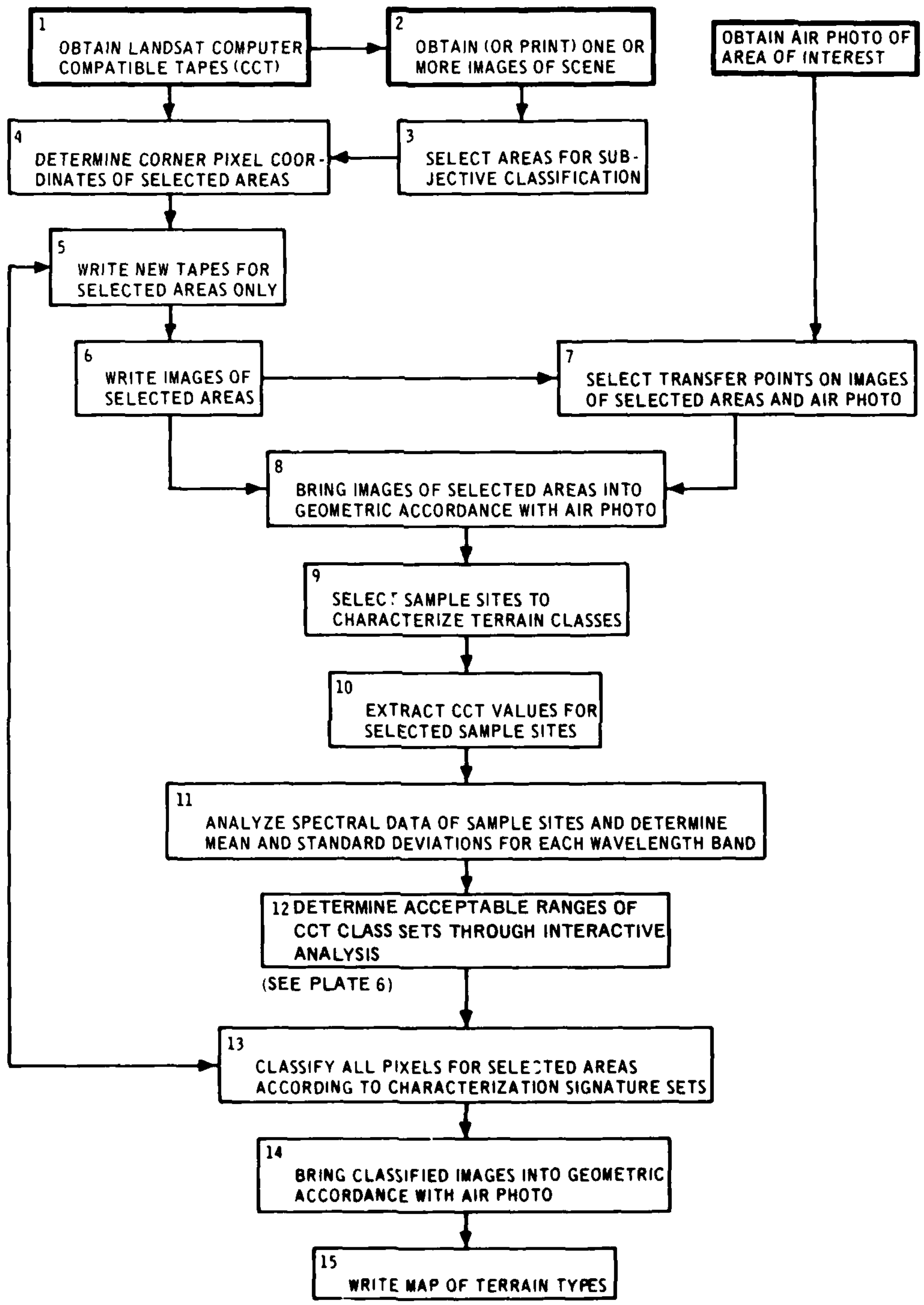
DETAILS OF SLOPE CORRECTION PROCEDURE USED IN BLOCK 8, PLATE 1

PLATE 3



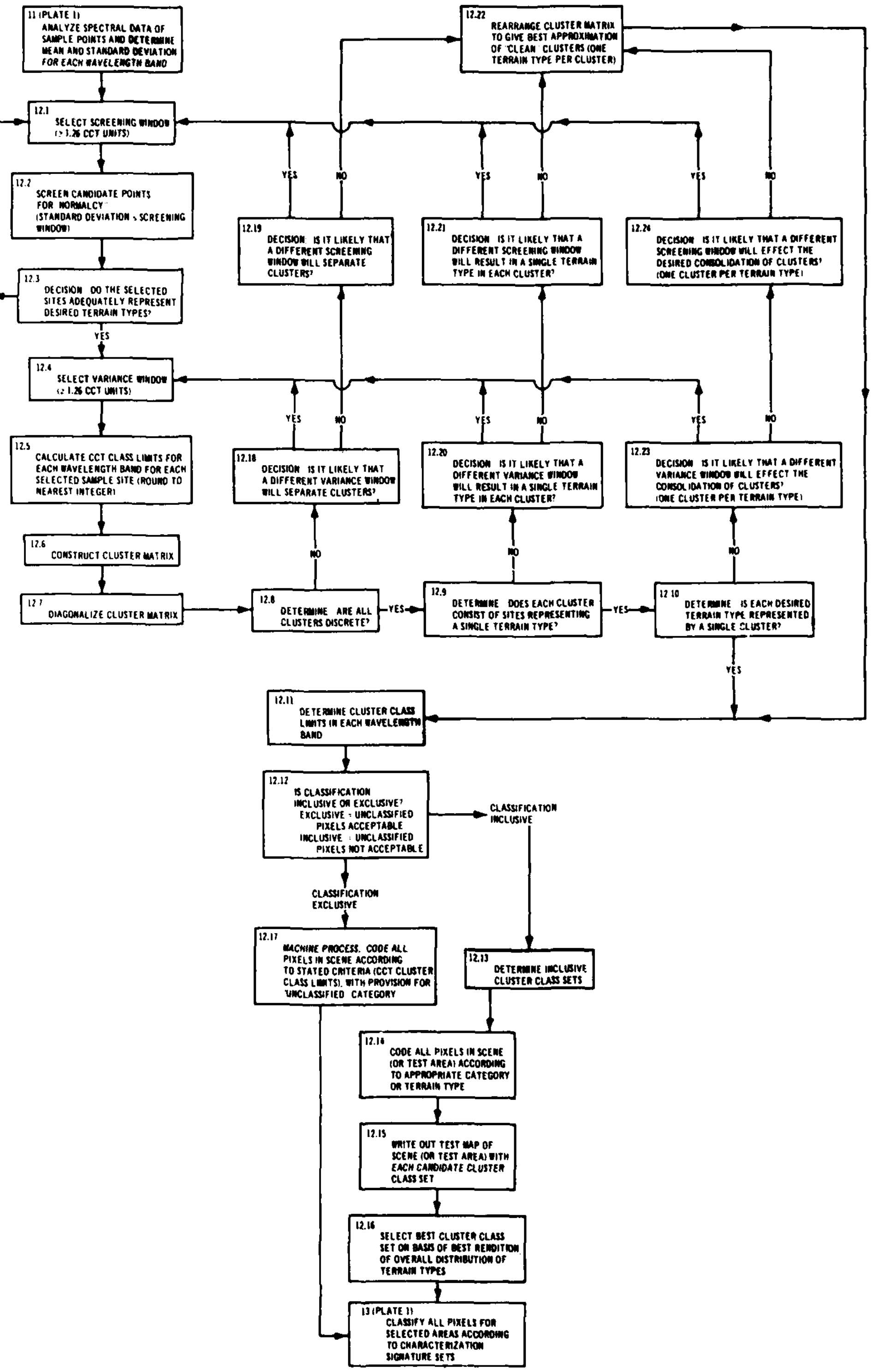
DETAILS OF SHADOW CORRECTION PROCEDURE USED IN BLOCK 8, PLATE 1

PLATE 4



GENERALIZED FLOW DIAGRAM OF PROCEDURE FOR GUIDED CLASSIFICATION

PLATE 5



PROCEDURE FOR SELECTING APPROPRIATE CLASSIFICATION CRITERIA

PLATE 6

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Smith, Margaret H
  Acquisition of terrain information using Landsat multispectral data; Report 3: Application of an interactive classification procedure in South Louisiana / by Margaret H. Smith, Horton Struve. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.
  87, [24] p., [3] leaves of plates : ill. ; 27 cm.
(Technical report - U. S. Army Engineer Waterways Experiment Station ; M-77-2, Report 3)
  Prepared for Assistant Secretary of the Army (R&D), Department of the Army, Washington, D. C., under Project 4A161101A91D, Task 02, Work Unit 110-Q6 and Earth Resources Satellite Program, Work Unit 31584.
1. Data acquisition. 2. Landsat (Satellite). 3. Multispectral data. 4. Spectrum analysis. 5. Terrain classification. I. Struve, Horton, joint author. II. United States. Assistant Secretary of the Army (Research and Development). III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; M-77-2, Report 3.
TA7.W34 no.M-77-2 Report 3